Ontario

THE FUTURE OF MINERAL DEVELOPMENT IN THE PROVINCE OF ONTARIO NORTH OF 50°

Prepared by
Laurentian University

the ROYAL COMMISSION on the NORTHERN ENVIRONMENT

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THE NORTHERN ENVIRONMENT

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ERRATA

p. xi In the case of silver, we project a decline in world consumption during the next two and one-half decades

This should be:

In the case of silver, we project an increase in world consumption of only 43 percent during the next two and one-half decades.

p. 21 Although we expect that the consumption of all of the minerals studied, with the exception of silver, will continue to increase in the future, the rate of growth is not likely to be as high as it has been in the past

This should be:

Although we expect that the consumption of all of the minerals studied will continue to increase in the future, the rate of growth is not likely to be as high as it has been in the recent past.

p. 132 The problem is that we expect world nickel production to increase by a factor of 10.7 during this period.

This should be:

The problem is that we expect world nickel production to increase by a factor of 2.4 during this period.

p. 146 Table II-7

	1980	1985	1990	1995	2000	2004
Gold	307	1,742	3,177	4,612	6,047	7,482

This should be:

	1980	1985	1990	1995	2000	2004
Gold	307	418	718	1,462	3,477	7,482

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In a research project as complex as this one the researchers receive a considerable amount of assistance, which deserves to be acknowledged. Our debts to others are considerable.

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To these individuals and groups and many others, we express our deep appreciation, but we accept full responsibility for the contents of our Report.

PREFACE

The research project proved to be a massive undertaking. As the work progressed, the nature of the project was altered considerably. What began as a basic economic feasibility study became a much broader exercise involving 25 year forecasts of mineral production, consumption and price. The original geological investigation methodology was altered at the request of the Commission. At the urging of a senior Commission official a new element, investment climate, was added.

The result of these changes is the production of a Report which differs somewhat from our original proposal. The scope of the project has expanded and consequently the precision and depth of the analysis has contracted.

Although we recognized that time and cost considerations imposed severe limitations upon our activities, the Commission was gracious in its willingness to extend our deadlines. This allowed us to complete a large number of studies. We have submitted some 2,000 pages of background material in twenty-odd Technical and Background Reports. It is from this material that we produced our Final Report.

It is important to point out that our work concentrated exclusively on the potential for development of undiscovered mineral deposits in that part of the Province of Ontario North 50°N. None of our analyses or conclusions are related to known mineral deposits in the region.

SUMMARY

(start on next page, x)

and to develop new ones. We found evidence which indicates that over $4.4 billion in investment is planned for the nickel industry. Chile expects to see $1.5 billion invested in molybdenum development. Within the U.S.A., $1.3 billion is planned to expand copper production, smelting and refining capacity. Brazil ambitiously plans to oversee $11 billion invested in the development of its iron ore resources during the 1980's.

Such investment supports our conclusion of mineral production growth. It also reflects and anticipates past and future growth in terms of mineral consumption.

From 1950-1979 world consumption of nickel increased by a factor of 5. By 1979 the world was consuming iron ore at levels 395% greater than those of 1950. For zinc, lead and silver, world consumption increased by factors of 3.9, 2.9, and 2.2, respectively.

Our consumption forecasts suggest continued growth for most minerals. By 2004 we expect world consumption of platinum to be 559% of what it was in 1980. Molybdenum consumption should increase by a factor of 2.3. For copper, zinc, lead, iron ore, and nickel, our analysis indicates increases in consumption by factors of 2.1, 2.1, 1.8, 1.7 and 1.7 respectively. In the case of silver, we project a decline in world consumption during the next two and one-half decades. By 1990 we expect that world uranium consumption will attain a level 242% greater than 1980 consumption levels.

The planned investment in expanded and new capacity throughout the world is based, in part, on assumptions that mineral prices will continue to rise. This pattern, apart from zinc,

(overleaf to xii)

The mining industry has been and continues to be a major element in the economy of Ontario. During the last three decades, however, Ontario's status as a world and Canadian mineral producer has declined. The growth of mineral production within the province has not kept pace with that of other provinces and other countries.

During the period from 1950 to 1979 there were some dramatic increases in world production of a number of minerals. By 1979 platinum production reached 1,590% of its 1950 levels. For molybdenum, the increase was by a factor of 7.2. World iron ore production was 434% of 1950 levels. Nickel production rose by a factor of 4.5. For copper, zinc, lead, silver and gold, world production over the three decades increased by factors of 3.2, 2.9, 2.3, 1.9, and 1.3, respectively. By 1979, world uranium production was 120% of 1960 production levels.

Our econometric analysis indicates similar growth in world mineral production during the years 1980-2004. We expect platinum production to be 558% of its 1980 levels by the end of the forecast period. For silver, an increase to 264% of 1980 levels is expected. Copper production should expand by a factor of 2.3. For nickel, zinc, iron ore, lead and gold, we predict production increases by factors of 2.2, 2.3, 1.9, 1.8 and 1.6, respectively. The only exception to this pattern of anticipated growth is uranium. Our analysis indicates that uranium production will decline and that by 2004 the world will produce only 83% of the amount of uranium which was produced in 1980.

In terms of planned investment, there a number of indications that massive amounts of money will be spent to expand existing sites

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has been the case from 1950 to 1979.

Real price increases occurred for most of the minerals examined in this study. In 1979 $US terms the price of molybdenum in 1979 was 465% of the 1950 price. Silver prices increased by a factor of 4.8. Uranium, gold, nickel, platinum, copper, lead and iron ore prices rose by factors of 4.7, 2.8, 1.9, 1.5, 1.4, 1.3 and 1.1, respectively. By 1979, zinc prices, in real terms, reached only 82% of their 1950 levels.

If we assume that the world economy will grow at the rate suggested by senior UN officials, then we expect mineral prices will continue to rise throughout the next 25 years. In the case of gold, particularly, our results beyond 1990 warrant considerable skepticism. Our econometric model forecasts that by the year 2004, gold prices will be 2,437% of their 1980 levels. We expect silver prices to increase by a factor of 6.8. Molybdenum, zinc, lead, nickel, copper, platinum and iron ore prices are expected to increase by factors of 6.4, 3.7, 2.8, 2.7, 2.6, 2.2 and 2.0 resprectively. During the period, we expect that the price of uranium will decline from its high levels of the late 1970's.

The analysis of production, consumption and price, as well as our review of planned investment activities, provides a basis from which we could determine who our major competitors for mineral development investment are likely to be. Twelve countries - Australia, Brazil, Chile, the Dominican Republic, Indonesia, Mexico, Peru, the Philippines, South Africa, Sweden, the U.S.A. and Zimbabwe - appear to offer considerable opportunities for mineral development in the future. The analysis of investment climate and political

risk indicates that Ontario continues to be highly regarded by potential investors. Should profitable deposits become found and proven, we are confident that the required investment to develop such resources in Northern Ontario will be forthcoming.

Clearly, no mineral development can take place unless mineral resources exist in the region. The geologists whom we consulted informed us that, in their opinion, some sixteen different types of ore bodies are likely to exist within the region. These include copper, copper-zinc, copper-lead-zinc, lead-zinc, nickel-copper, molybdenum, uranium, gold, silver, iron, lithium-columbium, coal, chromium, diamond, cobalt and platinum. The same experts indicated that mineral development was most likely to occur for copper-lead-zinc, nickel-copper, gold, silver, iron and coal deposits in the more accessible southern half of the region.

Our own analysis of internal rates of return indicated that at 1979 prices, a number of possible mineral deposits could produce, at optimum production levels, return on investment in excess of 15%. These included copper-zinc, copper-lead-zinc, lead-zinc, uranium, gold, lithium-columbium, and cobalt. In the case of uranium, this finding is quite misleading because of the drastic decline in uranium prices during the past few years.

We conducted sensitivity analysis to determine which factors were most likely to have the most serious effects on the potential profitability of new mining ventures in the area. The most sensitive factors were taxation, mineral prices, the size of the ore body, the grade of the ore body, mill recovery, mine recovery, dilution, development and capital costs. In this section of the

Report, a more thorough analysis of taxation indicates that tax changes, in the past, have had serious effects on profitability, the pay back period and exploration activity.

On the basis of these studies, an examination of patterns of mineral development in the province, and an examination of the prices required to provide an economically attractive return on investment for the potential mineral deposits, we are able to come to some more specific conclusions regarding the future of mineral development in the region.

Most of the mining activity and future development will occur in existing mining camp areas. Mining activity in the most remote Northern parts of the area is quite unlikely.

If the mineral deposits indicated by the geologists were found and were as large and rich as our information suggests, then a number of them might well be developed in the future. At optimum production levels, some gold deposits in the south-west part of the region would be economically feasible by the end of the 1980's. By the mid-1980's, copper-zinc deposits in the south-east and south-west sections of the region should be economically viable. At 1979 prices, using open pit mining methods, some copper-lead-zinc deposits are economically feasible. If cut and fill methods are used, copper-lead-zinc deposits in the south-east and south-west sections of the region would be economically feasible by the early 1990's. Lead-zinc deposits in the south-east and south-west parts of the study area should be attractive to investors by the early 1990's. By the mid 1990's the potential copper deposit in the south-east section of the region would be economically feasible. Nickel-copper deposits are unlikely to be economically

feasible before the end of the 1980's. If molybdenum deposits do exist and are found, they would be economically feasible by the latter half of the 1980's. By the late 1980's the potential silver deposits discussed in Chapter III of our Report may well be economically attractive investment opportunities.

The data which we collected and the various analyses which were undertaken by members of the project team indicate that mineral development could occur in the study region. Indeed, the Report presents a rather optimistic picture of future development opportunities. This impression must be treated cautiously. The mineral deposits discussed in this study have yet to be found. The world economy may not grow at the rates indicated by United Nations experts. Until the orebodies are found and proven and until prices rise to appropriate levels, no new development is likely to take place. It is our belief, however, that there is considerable potential for mineral development in the region North of 50°N in the Province of Ontario.

CHAPTER ONE

ONTARIO'S MINERAL INDUSTRY IN CONTEXT

It is virtually impossible to overstate the importance of the mining industry and mineral development to the Canadian economy. Indeed, one United Nations study suggests that the standard of living in a country is proportional to the per capita value of mineral production of that country.[1] To a large extent, the health of the Canadian economy is reflected by the relative health of the Canadian mining industry.

In 1979 the value of Canadian mineral production amounted to $12.4 billion (Canadian). Of this amount, $9.3 billion (Canadian) of our mineral production was exported to other countries.[2]

In 1979, 141,000 people worked directly for mining companies in Canada. These employees received $1.6 billion (Canadian) in salaries and wages in that year. If one included people indirectly employed by the mining industry, one could argue that mining and mining-related industries employed 9.3% of the labour force of Canada.

These figures have helped to demonstrate the very important role which mining plays in Canadian economic life. Fournier has argued that, in total, mining was responsible for 6.9% of the Gross National Product in 1979.

Just as mining plays an important role in Canadian economic life, Canada's mining industry plays an important role in terms of world mineral production. Canada is the fourth largest mineral producer in the world. Only the U.S.A., the USSR and South Africa produce more. Canada is the world leader in the production of nickel and zinc. It is the second largest producer of asbestos, potash, uranium, molybdenum, elemental sulphur and gypsum.[3]

Within Canada, the role of Ontario's mineral industry is second to none. In 1979, mineral production in Ontario amounted to 28% of the value of total Canadian production. This included 8,734,540 tonnes of minerals with a value of $2,441,038,000 (Canadian).[4] In the same year, mining companies operating in the province employed 47,000 workers and paid $554 million (Canadian) in salaries and wages.[5]

The image created by the preceding information must be viewed with caution. Increasingly, the mining industry in Canada is facing strong competition from abroad and a number of domestic difficulties. The following factual material may help to indicate at least one aspect of the situation.

Canada's status as a major mineral producer is being challenged. For each of the minerals indicated, Canada's share of world production has declined by 1977 and 1979 from its best position during the 1950 to 1979 period. In some cases, such as gold, this decline in share of world production has occurred over a fairly long period of time. In other cases, such as

molybdenum, Canada's share of world production appears to have reached a peak somewhat later in the 1950 to 1979 period.

This trend is an important one. Clearly, it suggests that Canada's share of world mineral markets is shrinking. It also indicates the presence of new and/or more powerful competitors in terms of mineral production throughout the world.[6]

In the case of Ontario, the situation is even more disturbing. Ontario's share of world and Canadian mineral production has declined considerably during the 1950 to 1979 period. The only exception to this trend is platinum. In 1979, Ontario's share of Canadian production of lead was only 88% of what it had been in 1972. In the case of gold, Ontario's share of Canadian production had dropped to 65% of what it had been in 1959. The situation for iron ore production had deteriorated even further. Ontario's production of iron ore in 1979 constituted only 20% of what it had been in 1950 in terms of total Canadian iron ore production.

What these statistics indicate is the declining position of Ontario within Canada and the rest of the world.[7] Ontario's competitors include not only foreign countries but also its provincial partners within Confederation as well as the territories.

Newfoundland has increased it share of Canadian production of copper, gold and iron ore. New Brunswick's pro-

duction of copper, gold, lead and silver has grown disproportionately to Ontario's production of the same minerals. Quebec has captured an increased amount of Canadian production of gold and iron ore. Manitoba's copper and nickel production has increased. Saskatchewan's uranium resources have competed with those of Ontario. British Columbia has improved its rankings in terms of production of copper, gold and molybdenum. The Northwest Territories has assumed an increased role in Canada insofar as the production of copper, gold, lead and silver are concerned. The production of copper, lead and silver in the Yukon has increased its share of total Canadian production for these minerals.[8]

Although it is clear that the mining industry plays an important part in the economic life of the Province of Ontario, it is also obvious that Ontario's mining industry occupies a less important position than it did formerly on the Canadian and world mineral production scenes. The only way in which Ontario can regain its more important position in Canadian and world mining is to increase its mineral production.

Although there may be some slack in terms of existing mines in Ontario, we feel that these mines do not have the capacity to alter, dramatically, the trend which has been outlined above. The only way by which significant increases in mineral production within the province can take place is through the development of mineral deposits which have not yet been mined.

Unless there is a dramatic shift in the policy of the provincial government in the direction of increased public investment, the capital required for such mineral development must come from the private sector. Private investors are not likely to risk millions of dollars unless they have some confidence that such investments are likely to produce a reasonable return.

To a large extent, the potential profitability of new mineral development is dependent upon international rather than purely domestic factors. These factors include demand for the mineral resource, alternative sources of supply, and the price which will be paid for the particular mineral by the world market. In addition, the availability of foreign capital for investment in Ontario mineral development projects is affected seriously by the perceived investment climates of Ontario and its competitors. These four elements constitute the major concerns examined in the following chapter.

NOTES

1. A. Fournier, L'Industrie minière. (mimeo, January 1981).
2. Canadian Mines Handbook, 1980-81.
3. Correspondence, Dr. J. Zwartendyk, Energy, Mines and Resources Canada, 26 March, 1982.
4. Canadian Mines Handbook, 1980-81.
5. A. Fournier, L'Industrie minière. p. 5.
6. For more detail, see Table I-1, Appendix A, p. 138.
7. For more detail, see Table I-2, Appendix A, p. 139.
8. For details see H. Strauss, Technical Information Paper No. 2. Prepared for the Royal Commission on the Northern Environment, April, 1981.

CHAPTER TWO

INTERNATIONAL FACTORS WHICH MAY AFFECT MINERAL DEVELOPMENT ACTIVITY IN ONTARIO

In this chapter of our report we focus on international factors which are largely beyond the control of a single country or province. Clearly, it is impossible to deal with all of the aspects of the international political, economic and social systems which affect the mineral industry. We concentrate our attention, albeit briefly, on five important considerations - mineral production, mineral consumption, mineral prices, the identification of existing and future competitors in mineral markets and an analysis of the investment climates of ourselves and our major competitors. Basically, this chapter attempts to provide some indication of whether or not investment capital is likely to be forthcoming should a large, high-grade mineral deposit be found in the study area.

These largely economic aspects of the project are treated from three somewhat different perspectives. An historical review of price, production and consumption, indicates patterns from 1950-1979. The development and application of econometric analysis provides future values of consumption production and price. Finally, we present an analysis of studies of investment climates of our potential competitors who have been identified by the previous two approaches.

The most difficult of the three approaches is the econometric modelling. The model is developed to provide the fore-

casts of consumption, production and price of the ten minerals with which this study primarily is concerned. It is based on traditional supply and demand analysis. It refines and extends other econometric models which have been developed in the past.[1]

Because the Commission specifically requested forecasts up to the year 2004, these have been presented. It is important to state that the authors have very serious reservations about the projected values beyond the year 1990.[2] In most cases, we feel that these values are inflated because of the effects on the model of estimates of world economic growth provided by UN experts for the period in question.

Dr. Willauer and Dr. Strauss have attempted to verify the accuracy of the model's predictions in two ways. They compared the projected production figures with those of other experts in the field including Dr. L. Malenbaum[3] and the U.S. Bureau of Mines[4]. In some specific cases, such as platinum group minerals, they compared their production projections with detailed analyses done by researchers such as T.P. Mohide[5]. The second check involved use of the model to provide consumption, production and price figures for the 10 minerals during the 1950 to 1979 period. These simulated figures were then compared with the actual statistics.[6] Although the results of the econometric model did produce some surprises,[7] in the vast majority of cases, the results were compatible with what other researchers have anticipated.

Mineral Production

During the 1950 to 1979 period, gold production increased by a factor of 1.3. Nickel production expanded by approximately 450%. Silver production was up by about 190%. World lead output had grown by a factor of 2.3. For zinc, the increase in production was 285%. Copper production increased by a factor of 3.2. Molybdenum and platinum production increased more dramatically than was the case for any of the other minerals studied. From 1950 to 1979, the production of molybdenum expanded by 720% and platinum production increased by almost 1,590%. During the same period iron ore production had grown to 434% of its 1950 levels. Uranium production also increased to the extent that by 1979 the world produced 120% of what had been mined in 1960.

This pattern of growth for all of the minerals examined in this study during the 1950 to 1979 period undergoes some changes when one examines our forecast production levels for the years 1980-2004 and compares the 2004 levels with the 1950 production statistics.

Our econometric model forecasts an actual decline in world gold production by 2004. It indicates that world gold

production will amount to only 53% of 1950 gold production levels. Even the revised forecast prepared by Dr. Strauss indicates relatively little growth in world gold production by the year 2000. He expects world gold production to be only 160% of what it was in 1950.

Platinum production forecasts also provide some unanticipated results. The forecast value for 2004 is 10,500% higher than the actual 1950 production. The discrepancy between our forecast and those of other experts in this field is discussed in some length in the Report on Platinum.[8]

For the other minerals, the predicted output levels reflect continued growth in a pattern not unlike that of the 1950-1979 period. We expect that nickel output will be 1,070% greater than it was in 1950. For silver, the increase is in the order of 550%. For lead, the expansion in production reaches approximately 440% of 1950 levels. We anticipate that zinc production will increase to about 596% of 1950 production. Copper production should rise by a factor of 7.8 over 1950 output. Molybdenum continues to be most impressive and we expect that by 2004, the world will be producing 1,720% more of this modern metal than it did in 1950. Iron ore production forecasts suggest that production levels by 2004 will be 883% of 1950 iron ore production.

Uranium production forecasts indicate very limited growth. Indeed the statistics suggest only a relatively

slight increase of uranium production by the year 2004 as compared to 1960 production. The reasons for this rather pessimistic projection are discussed in the Report on Radioactive Fuel Minerals.

This picture is perhaps more reassuring than it should be. If there are to be continuing increases in the production of minerals in the future, then there may well be opportunities for increased mineral output in Ontario. In general, however, developments within the province have not moved in this direction. With a few exceptions, Ontario's share of world mineral production has declined over the preceeding 30 years. Even in cases where Ontario has increased mineral output, this expansion has not taken place as dramatically as increases in world mineral production.[9]

The situation for the future is a mixed one. In the case of some minerals, Canada's and Ontario's positions are quite vulnerable. In other cases, some real opportunities exist.

In the case of gold we feel that the Canadian industry has a " great opportunity to regain part of the significance it lost as a world producer." [10] For nickel, the picture is less bright.[11] Canada and Ontario are likely to face increased competition from alternative suppliers especially those with lateritic ore deposits. In all probability the Canadian share of world nickel production will continue to decline. Silver may provide greater cpportunities because Canada is estimated

to possess the fourth largest reserve in the world.[12] Canada's position in terms of lead is highly vulnerable because " other countries import lead ores and concentrates only if they cannot avoid it due to a lack of domestic mineral resources and secondary lead."[13] We see little change in the status of Ontario as a lead producer unless significant ore bodies are discovered and developed. Such a development might occur because Canada is estimated to be the second largest holder of lead reserves in the world.[14] Zinc is a mineral with which Canada and Ontario are blessed in abundance.[15] Canada possesses the largest share of world zinc reserves. Ontario's role is significant on the world stage at the present time but its future may be less bright. " Ontario needs more zinc ore as present mines will be depleted by the year 2000".[16] Canada's reserves of molybdenum and its production of this mineral are significant internationally. " Unless substantial high-grade reserves could be ascertained - an unlikely event due to a geological structure which differs from the normal porphyry-type, molybdenum - bearing rocks - Ontario will remain on the sideline."[17] Ontario's expansion of platinum production has been slower than that of the world. Canada does possess significant reserves. Ontario possesses potential platinum deposits in the Lac Des Isles region. In addition there have been significant traces of platinum in ash from the Onakawana Lignite deposits.[18] By the mid-1980's it has been reported that there will be refining capacity within the pro-

vince. Dr. Strauss notes, however, that it is of "critical importance to have more companies with more refineries involved in the production and marketing of these metals"[19] Ontario continues to be a significant world producer of copper. Canada's long-term reserves of copper are estimated to be the third largest in the world.[20] We expect that there will be considerable opportunity to expand copper production in Ontario in the future, but we note that producers are likely to face increased competition for markets and investment.[21] For iron ore resource development, we probably must wait until the turn of the century. Ontario possesses considerable iron ore reserves and Dr. Strauss suggests that " by the end of the century, excellent opportunities will present themselves for the chief iron ore resource holders of the world." [22] Although Ontario's uranium resources are abundant, it appears that significant future development will not occur until far into the next century. Indeed, Dr. Strauss emphasizes that " at least until the end of this century, there is no purpose in sinking more capital into new uranium ventures in this province." Even this conclusion may be somewhat optimistic in the light of projections provided in the <u>Report on Radioactive Fuel Minerals</u>.

In an effort to determine which countries are likely to be major competitors of Canada and Ontario in the expansion of mineral output, we have examined two aspects of the mineral industry. One of these is the long-run reserves of various

countries as estimated by a variety of experts. A second consideration involved the analysis of current and planned investment in mineral production expansion by various countries.

In the case of nickel, eight areas - New Caledonia, Cuba, Canada, U.S.A., U.S.S.R., Australia, the Philippines and Indonesia - each possess 4% or more of the world's total reserves.[24] Investment in New Caledonia is expected to be about $800 million. Cuba is planning a $600 million expansion of its nickel producing facilities. The U.S.A. has recently added nickel to the priority list of its strategic stockpile. The U.S.S.R. has planned to spend about 1 billion roubles to expand its nickel output. In Australia about $100 million is being invested in the development of new deposits. We foresee a doubling of nickel production in the Philippines in the future and by the late 1980's Indonesia will double and perhaps even triple its production of nickel. At the present time it appears that alternative suppliers are currently investing or plan to invest over $4.4 billion in expansion of nickel production.

We expect some dramatic changes in gold production in the future.[25] Currently, South Africa, the U.S.S.R., the U.S.A. and Canada possess collectively 85% of the known gold deposits. We expect that gold production in South Africa will begin to decline after 1887. In the U.S.S.R. there is expansion of the Mogadan Oblast enterprise which already contains about 35 placer mines. The U.S.A. will experience an additional

$168 million in investment to expand domestic gold production. We expect that Brazil will become one of the most important world gold producers of the future. Other South American countries also will increase gold production in the future.

The U.S.S.R., U.S.A., Mexico, Canada, Peru and Australia possess the largest reserves of silver.[26] The U.S.S.R. has been expanding production faster than the world as a whole and we expect this to continue. The U.S.A. is experiencing large investment in order to expand silver production. Mexico plans to increase its annual production of silver by 450-500 metric tons by 1983. Peru is attempting to develop its silver producing capacity and in Australia new investment is responsible for the development of deposits.

Canada, the U.S.A., Australia, the U.S.S.R. and Ireland possess the largest reserves of zinc.[27] It appears that the U.S.A. will experience little expansion of zinc production in the near future. Australia is bringing new zinc producing mines on stream now. The U.S.S.R. is dependent on imports of zinc at the present time and we do not see much evidence of any large expansion of its zinc output in the foreseeable future. Mexico, however, has committed $280 million to expand its lead and zinc output potential.

The U.S.A., Canada, the U.S.S.R., Australia and Mexico have the largest reserves of lead in the world.[28] There is relatively little investment taking place in the U.S.A. at

the present time. Plant modernisation and increased efficiencies in existing operations should result in somewhat increased lead production in the U.S.A. Although the U.S.S.R. is continuing to expand its lead production, it will continue to be dependent on lead imports to meet its domestic needs. Australia is developing new mines and expanding existing operations. Approximately $235 million is being invested to expand Australia's lead smelting and refining capacities. Mexico plans to increase its mining and concentrate capacity by 65% by the early 1980's.

The U.S.A., Canada, Chile and the U.S.S.R. have the largest reserves of molybdenum in the world.[29] We expect that the U.S.A. will continue to expand its production. Chile has planned to invest $749 million to expand production. Total investment in molybdenum production in Chile will reach $1.5 billion when all projects planned are completed. We do not foresee any great threat from the U.S.S.R. It will continue to be dependent on imports of molybdenum.

South Africa, the U.S.A., the U.S.S.R., Zimbabwe, and Canada possess the largest reserves of platinum in the world.[30] South Africa is likely to continue expanding its production and will remain the largest producer of platinum in the foreseeable future. The U.S.A. will continue to remain dependent on imports, but increases in domestic production will reduce this dependence somewhat in the future. We expect that the U.S.S.R. will continue to expand its production at a rate which

is faster than that of total world production in the future.

The U.S.A., Chile, Canada, the U.S.S.R., Zambia and Peru possess the largest reserves of copper in the world.[31] Investment of $1.29 billion in the U.S.A. is expected to aid in that country's effort to double output by the year 2000. Chile plans to invest $6.76 billion in its copper industry in the 1980's. The U.S.S.R. envisages an increase of 13-15% in copper production in any given 5 year cycle in the next few decades. Zambia is currently assessing alternative prospects for expansion of its copper output. Peru expects to experience $2.86 billion of investment in the early 1980's to increase its output by almost 300,000 metric tons. Mexico too is planning serious increases in copper production by means of five new major investments in its mineral industry.

The U.S.S.R., Canada, Brazil and Australia possess the largest shares of the world's iron ore reserves.[32] By the early 1980's approximately $1.2 billion will be invested in expansion of iron ore production in Brazil. The Brazilian master plan calls for an investment of $11 billion by 1988 in iron ore resource development. The U.S.S.R. has been expanding its iron ore production considerably in the recent past and we expect the rate of expansion to continue. For the foreseeable future, the U.S.S.R. is likely to increase iron ore production by 4 million metric tons per year. In Australia, current plans call for investment of about $1 billion

in iron ore development. By 1989, it is expected that a 21 percent increase or more in iron ore production will have taken place in Australia.

Australia, the U.S.A., South Africa and Canada possess the largest reserves of uranium in the world.[33] Approximately $900 million of investment is taking place or planned for the development of uranium resources in Australia. In South Africa over $450 million of investment is in place. In the U.S.A., nine new uranium projects have been planned for the 1981-1984 period. Five of these are being cut-back due to the weak market conditions of the current period. Gulf Oil, however, appears to be proceeding with a $500 million investment which should produce about 3,800 metric tons of ore daily by 1984. In any case, the U.S.A. has the potential to respond quickly to market pressures.

Consumption

It should be noted that consumption statistics for gold, molybdenum, uranium, and platinum are not provided. This occurs because reliable statistics on world consumption of these minerals have not be found. Although we exclude only gold consumption projections, we advise the reader to accept the values with con-considerable caution, especially in the case of silver.

The consumption of nickel increased by approximately 505% from 1950 to 1979. In the case of silver, the increase

amounted to 215%. Lead consumption expanded by 293%; the consumption of zinc grew by 311%; for copper, the increase was 371%; and for iron the consumption growth was 395%.

The growth in consumption of the minerals examined will not be as dramatic in the 1980-2004 period as it was during the interval from 1950-1979. We expect nickel consumption to increase by 170% from 1980 to 2004. In the case of silver, an increase of 143% in consumption is predicted. Lead, in our opinion, will experience increased consumption by about 178%. For zinc, molybdenum, platinum and copper the growth should amount to about 209%, 229%, 559%, and 214%, respectively. In the case of iron ore we project an increase in consumption of approximately 174%. Uranium consumption forecasts cover only the period from 1980-1990. During this decade, we expect an increase in consumption of about 242%.

The reasons for this growth are twofold. On the one hand, developing countries proceeding on their courses of industrialization will consume increasingly large shares of mineral production. Consumption patterns in industrial countries for most minerals appear to be relatively stable. On the other hand, technological innovation may result in increased consumption of certain minerals.

The development of fibre optics should lead to increased consumption of platinum.[34] Platinum catalysts are likely to become important features of newly developed fuel cells. Molybdenum is in particular demand for the production of specialty

steels for the energy and nuclear industries. Molybdenum consumption is likely to be very positively affected by increasing high technology in the future.[35] Lead consumption involves the future of the automobile. Mined lead is likely to continue to face increased competition from recycled lead as a gasoline additive and for conventional and some newer forms of batteries.[36] The use of zinc to galvanise sheet metal is expanding considerably and we expect that this aspect of zinc consumption will continue to grow in the future.[37] The future for silver consumption appears to be much more pessimistic. This is because of the probable de-silverisation of photography which we expect to take place in the late 1980's or early 1990's.[38] Nickel consumption should continue to rise because of the demand for stainless and other nickel-alloy steels. Should the nickel battery become proven and the need for electric cars increase, then this would provide a further stimulus to nickel consumption.[39] In the case of gold " world demand for gold for the electronics industry may be rising, though at a rapidly decreasing rate."[40] Copper should continue to be needed in increased amounts for electrical energy transmission, but it does face considerable future competition from optical fibres in the telecommunications industry.[41] The increasing demand for electrical energy has, and will continue to stimulate the growth of nuclear reactors, which require uranium and/or thorium.[42]

In the case of iron ore, all developing and industrialising countries will follow the examples set by countries such as Mexico, Spain, Brazil and Romania and rapidly expand their iron and steel industries. In turn, these developments will not fail to impose increasing pressures on the demand for iron ores." [43]

Although we expect that the consumption of all of the minerals studied, with the exception of silver, will continue to increase in the future, the rate of growth is not likely to be as high as it has been in the recent past. Zinc, molybednum, copper and especially the platinum group metals should experience larger consumption increases than the six other minerals examined in this project.

Price

During the 1950-1979 period, an inconsistent pattern, insofar as mineral prices are concerned, has been detected. Some minerals such as silver, uranium and molybdenum experienced rather dramatic increases in price (484%, 477% and 465% in 1979 $U.S.). Nickel prices grew to approximately 196% of their 1950 value. The prices of gold, platinum, copper, lead and iron ore increased by factors of 2.85, 1.47, 1.39, 1.28 and 1.07 respectively. For zinc the situation was quite different. In constant dollars, the price of zinc in 1979 was only 83% of what it had been in 1950.

Our forecast prices cover the period from 1980 to 2004.

The predicted prices pattern is somewhat less eclectic than was the case for the previous period. Gold presents a dramatic exception and our econometrically derived forecast price for 2004 is 2437% of the 1980 price. Once again, the note of caution presented earlier in this chapter and underlined strongly in the Report on Gold is emphasized in this particular case. We expect that the price of silver will increase by 684% and that the price of molybdenum will climb to 642% of its 1980 value. Zinc prices are projected to grow by approximately 370%. The increases in price for lead, nickel, copper, platinum, and iron are projected to be about 279%, 272%, 255%, 220%, and 198% respectively.

The situation, insofar as uranium prices are concerned, is quite different from that presented above. Our forecast indicates that the price of uranium will actually decline to about 50% of its 1980 price. To a large extent, this apparent anomoly can be explained by production levels which are not matched by consumption. Only when additional requirements for fuel for new reactors becomes evident at the turn of the century should we expect to see some strong upward movement in uranium prices.[44]

In terms of price increases, it appears that silver and molybdenum are the twc minerals which should experience the strongest upward movement of the ten minerals examined in our economic analyses.

Investment Climate

New mineral developments are expensive and require massive amounts of capital over a considerable period of time before some return on investment can be realised. A potential investor is likely to be concerned about two types of risk. The first of these is the stability of the political system generally and more particularly, the stability of the attitude of government towards such private investment.[45] The behaviour of the french stock exchange following the election of François Mitterand as President is an example of investors' reaction to perceived dramatic political change in that country. The second major risk relates to the potential profitability of the investment. Obviously, capital is more likely to be attracted to investment opportunities where the profit margin is likely to be best.

The mining industry of Ontario has been developed primarily through private investment. The re-election of the Progressive Conservative government in 1981 suggests that the vast majority of investment in mineral development in the province is likely to follow the historical pattern. It is also likely that Ontario's reliance on foreign investment will continue.[46]

In view of this, the perceived investment climate of Ontario as compared with that of our potential mineral development investment competitors is important. Even if major new mineral deposits exist and are found within the province, they will not be developed unless investors are prepared to risk the capital resources that such ventures require.

In previous sections of this chapter we examined briefly the price, consumption and supply situations for ten minerals. The analysis of past-future supply of mineral resources allows us to identify our probable competitors in the search for mineral development investment.

In a technical report prepared for the Royal Commission we identified some twenty-two countries which have been major suppliers of one or more minerals on the world market. It should be noted that the U.S.S.R., Eastern European countries and other communist states have been excluded because " of the low likelihood of significant ... investment in them in the near future and also because of the very different political considerations involved in such investments." [47]

On the basis of the previous report and the individual mineral reports submitted to the Commission by Dr. H. Strauss[48] we have reduced the number of potential competing countries by 12. Each of these countries is and is likely to continue to be a major world producer of two or more of the ten minerals with which our study is concerned. These countries are Australia, Brazil, Chile, the Dominican Republic, Indonesia, Mexico, Peru, the Philippines, the Republic of South Africa, Sweden, the United States of America, and Zimbabwe (Rhodesia). By examining each of these countries in turn we may be able to assess the relative attractiveness of Ontario for mineral development investment.

Australia

Australia is a major producer of copper, gold, iron, ore, lead nickel, platinum and silver.

Australia continues to be one of Canada's most formidable competitors in the search for foreign investment. It is one of the most politically stable countries in the world and does not suffer from the threat of secession as does Canada.

The mineral industry is a healthy one in Australia. The Sydney Index of minerals and metals increased by sixty-nine percent in 1979. The New York Times reported a $17 billion dollar investment in the mining industry of the country on January 19. This involved five new aluminum smelters, new coal mines and three uranium mine developments. On January 16, Prime Minister Ohira of Japan called for a growth in co-operation between Japan and Australia in the development of Australia's natural resources.

In 1979, the Financial Times reported that BP was investing $1.5 billion to develop, in co-operation with an Australian company, copper, uranium and gold deposits in the Roxby Downs area of South Australia.

This impressive record does not contain some of the more problematic factors which affect mineral development in Australia. In his presidential address to the ANZAAS Congress on 14 May 1980, A.H. Parbo indicates that some of these include the lack of large Australian mining companies and the imposition of environmental protection regulations.

Recently, the aborigines called for a halt to all mineral exploration for three years on aboriginal lands. They expressed particular concern for land which is sacred to them. Thus far, the government has expressed little sympathy with this position.

The government is taking an increasingly interventionist role, however. New mineral export regulations were introduced in 1978. They involved government supervision of mineral exporters' negotiations regarding pricing, duration and tonnage for minerals such as coal, iron ore, bauxite and aluminum. The March 26, 1979 issue of the Journal of Commerce reported that the government is in favour of additional processing of minerals within Australia and is actively considering a number of policy options in that regard.

Although the BERI rating places Australia five positions lower than Canada.[49] We suspect that Australia will pose a stiff challenge to Canada for investment in the mineral industry. This is particularly true because of the decline of copper production in Japan and the proximity of Australian deposits to the Japanese industrial core.

Brazil

Brazil is a major producer of iron ore.

In the past Brazil has been viewed as one of the most secure investment locations in South America. This was partly due to the strong economic growth from 1964 onwards. The Economist reported that GNP " trebled since 1964".[50]

Unfortunately, President Figueiredo, who assumed office on March 15, 1979, now faces a much less optimistic economic future. The _Banker_ reports an inflation rate of 77% in 1979.[51] The trade deficit for 1979 amounts to over $2 billion and Brazilian currency has been devalued by 93% in the same year.

Although President Figueiredo announced his desire to move towards democracy, most observers feel that this will be a rather slow process. Internal opposition in the form of urban guerilla movements has not been too widespread. Although strikes by dockworkers and metalworkers earlier this year involved some violence, the government intervened quickly with troops to end the disputes.

The _Economist Survey_ does suggest that a credit squeeze policy as part of an inflation-fighting economic policy could bring on " explosive" reaction from trade unions. The same report also notes that Brazil's relations with both Argentina and the U.S. are worsening.[52]

Insofar as foreign investment is concerned, the Brazilian government appears to be moving in a more interventionist direction. On October 1, 1979, new rules were introduced to prevent multinationals from developing dominance in the manufacturing sector. Increasingly, joint ventures have become the preferred mechanism for investment. The _Financial Times_ reported on August 3, 1979, that Spain and Brazil had agreed to jointly develop the production of iron ore pellets in Brazil.

All five of the risk indices summarized in Appendix B indicate less confidence in Brazil than in Canada. In addition, the Institutional Investor Rankings show a drop in rank for Brazil of 10 places from 1979 to 1980.[53]

On this basis, it would appear that Canada will continue to be a more attractive investment than Brazil for the foreseeable future.

<u>Chile</u>

Chile is a major producer of copper and silver.

After Allende was removed from office and the authoritarian regime of General Pinochet took over, dramatic improvements in the state of the Chilean economy began to take place. Inflation, which reached 1,000% in 1973 was reduced to approximately 38% in 1979. Real growth was 7.3% in 1978 and 7.5% in 1979.

On the negative side of the picture is unemployment. It remains at about 12%. The energy crisis, particularly the loss of supply from Ecuador and Iran, has forced the country to go to the spot-market and this appears to be preventing any significant decrease in inflation in the near future.

Although the large mines were nationalized in 1971, the current government has attempted to attract foreign investment. In 1977, the Pinochet government passed new laws which removed

limits on the remittance of profits and granted foreign investors the same rights as local investors. In the past two years, \$200 million of foreign capital has been invested in the Chilean mining industry.[54] Time reported in January 1980, that by the end of the 1980's it was expected that \$5 billion in new foreign capital would be poured into the Chilean economy.[55]

This change in the investment climate is one reason why Exxon is currently considering a \$1.2 billion investment in Chilean copper production.[56] Such a move reflects the attractiveness of the policy of the Chilean government, announced in 1978, of allowing foreign investors to own smaller ore bodies in the country.

Exxon is hesitating because of what has been described as an " uncertainty factor" .[57] This reflects some of the political and social conditions of the country.

In terms of its external relations, Chile has not dramatically improved its position. In 1978-79 the Beagle Channel dispute with Argentina threatened to result in armed hostilities. This was averted by the timely mediation efforts of the Vatican. In January 1979 Peru expelled Chilean diplomats in Lima. Peru accused Chile of attempting to undermine the Peruvian Government. In 1979 the United Nations Human Rights Commission Report pointed to the numerous violations of fundamental human rights which the Pinochet government has condoned and carried out in recent years.

In general terms, however, there does not appear to be any serious threat to the stability of the Chilean political system from outside its borders. The somewhat more serious threats appear to be internal.

One of the most important of these internal forces has been the union movement. As a result of a number of politically motivated strikes in 1977 and 1978, the government banned the miners' union on October 19, 1978. The government also extended its state of emergency for a further period to September 1980. The new labour laws which were promulgated in July of 1979 did little to appease the miners. The law allowed miners to strike legally for only sixty days. After thirty days of strike, the mining company was legally empowered to lockout its workers and hire replacements. This law resulted in a costly strike at El Teniente, the largest of Chile's copper mines.

Although there is opposition within the country to the government, the Pinochet Government has demonstrated a consistent ability to maintain power and control. Unlesss there are some unforeseen developments, it is expected that the country will remain relatively stable internally.

For these reasons, we must conclude that Chile will be an attractive investment opportunity in the future. It may be able to attract capital which might otherwise have gone into the development of the Canadian mining industry. Chile, clearly, is likely to continue to be a serious competitor in the search for investment capital.

Dominican Republic

The Dominican Republic is a major producer of nickel and gold.

The recent political history of the Dominican Republic has been a stormy one. In 1973 a state of emergency was declared when guerilla forces landed inside the country. This experience repeated itself in 1975. President Guzman, who assumed office in 1978, declared a political amnesty in September 1979. Unfortunately, the government's response to its growing economic difficulties exacerbated the internal political situation and violence erupted in May of 1980. The threat of a general strike prompted the government to arrest a number of union leaders in June and many union leaders went into hiding and indicated support for a variety of opposition groups.

In the past few years, the economy of the country has weakened. The budget deficit in 1979 was $345 million and continued to increase into 1980. The government's freeze on public employee wages and increased charges for electricity, oil and gas provoked the unions and employees.

On May 28, 1980, the Governor of the Central Bank resigned. He argued that the Bank was printing new money to cover the budgetary shortfall and that, in his opinion, this was a policy which he would not support.

In an effort to improve its economic outlook, the Dominican Republic is actively searching for foreign investment. It has established three free zones where assembly operations are conducted with Government incentives.

In the field of mineral development, however, the Dominican Republic is not so encouraging. " In actuality, there exists a series of areas which are reserved for national investment, such as public utilities ..., mines and hydrocarbons ... ."[58] In addition, the normally generous Foreign Investment Law does not apply to the mining sector of economy and a much more complex set of mining laws creates some confusion.

The risk indices confirm the impression indicated previously. The Dominican Republic is consistently ranked much lower than Canada. Frost and Sullivan forecast a medium level risk of large scale political change.[59]

On this basis, it would appear that Canada has relatively little to fear from the Dominican Republic in terms of investment attractiveness.

<u>Indonesia</u>

Indonesia is a major producer of copper and nickel.

The situation, insofar as Indonesia is concerned, is the easiest to present because of the consensus of a number of observers.

In a 1978 study Rummel and Heenan predict that Indonesia faces a difficult future. They project greater political instability due to a internal turmoil than in any period since

the 1950's. They also claim that the external debt position of the country has reached "crisis" proportions and they expect an increase in what they describe as "creeping" expropriation. In general, they rate the country as a rather high risk for potential investors.[60]

This conclusion is supported by a number of recent risk indices. The BERI rating for Indonesia is 45.5 (high risk). The BI rating is 58 (moderately high risk). The WPRF suggests a 31% probability of investment losses in the next eighteen months and a 45% probability of investment losses in the next five years.[61]

On this basis, it seems clear that Indonesia is not likely to be a major competitor in the search for foreign capital for mining development in the near future.

<u>Mexico</u>

Mexico is a major producer of lead, silver, and zinc.

Mexico continues to demonstrate a high degree of political stability. President Echeverria has been replaced by President Lopez Portillo and the recent election of Miguel de la Madrid Hurtado demonstrated once again the stability of the Mexican Government. In addition, there does not appear to be any serious internal or external force which threatens the integrity of the state and its existing constitution.

Because of its extensive reserves of oil, now estimated at 50 billion barrels, Mexico's economy is becoming increasingly dependent on this valuable resource. Mexico plans on using its new economic clout to diversify and upgrade its economy. France, West Germany, Sweden, Japan, Canada and the U.S. have expressed interest in joint ventures.

The June 1, 1979 issue of the Latin America Economic Report indicated a protectionist approach on the part of the Mexican government. Foreign investment in high technology and/or labour intensive industry would be welcomed. The 1972 law which required that 51% of all companies' stock be sold into Mexican Lands continued to be a major part of the Mexican government's policy towards multinational corporation investment in the country. Despite this protectionism the June 13, 1980 Latin American Weekly Report predicted that there would be more than $1 billion of direct U.S. investment in Mexico during 1980.

Despite this investment, not all of Mexico's economy is so healthy. Unemployment is high. Inflation is a major concern. "Non-oil exports are stagnating".[62] Mexico continues to refuse to join the General Agreement on Tariffs and Trade (Gatt).

This basic economic weakness and the protectionist policies of the government are reflected in the risk evaluations. In all five of the rankings for which Canadian and Mexican ratings appear, Canada is more highly placed than is Mexico.[63]

It appears that although Mexico may have considerable attractiveness and influence because of its oil resources, investors still feel that Canada continues to be a more secure place in which to invest.

Peru

Peru is a major producer of copper, lead, silver and zinc.

The economic picture insofar as Peru is concerned is not as optimistic as that for Chile. Because of the financial difficulties of the Peruvian government, the IMF approved SDR of 184,000,000 until December 1980. A special arrangement with foreign creditors has been established. Only 10% of the foreign debt due in the 1979-80 period will be paid immediately. The remaining 90% ($568,000,000) will be repaid over a seven year period beginning in 1982.

The major note of optimism, in terms of its economy, is the discovery of additional oil deposits in the late 1970's. This has encouraged the Central Bank of Peru to predict a balance of payments surplus of $100 million in 1980.

The experience of the oil industry is revealing for our purposes. Occidental petroleum, a major investor in Peru, was affected by new economic laws which were introduced in 1980. Had the laws been applied retroactively, Occidental would have faced a bill of $110 million in back taxes. As a result of negotiations between Occidental and Peruvian officials an agreement was reached which gave the country an increased share of the profits realized by Occidental's petroleum activities in the country. This reflected a general pattern in many developing countries which Sachdev described well. He noted that "joint ventures are increasingly ending up in divorce."[64]

This increasing governmental activity is reflected in the mining industry as well. Metal Statistics 1977 reports the nationalization of the Cerro de Pasco mines. At the present time, the government owns a major share of the mining activities. There is, however, a large U.S. consortium which continues to operate a number of copper deposits in the country. One would expect that the patterns predicted by Sachdev will apply in this economic activity in the future.

Politically, Peru manifests somewhat less stability than Chile. Belaunde, who was subjected to a coup by the

Peruvian military in the mid 1970's has been re-elected President. This pattern of election, coup, election is a familiar one in Peru. At the present time, however, President Belaunde fails to hold majority support in the Peruvian Congress.

Partly because of a 70% inflation rate, Belaunde is attempting to attract foreign investment, particularly from the U.S. American reaction thus far has been one of skepticism.

Although there have been few incidents which affect the integrity of the state, there have been several internal disruptions in recent years. Miners' strikes are common examples. The August 1978 miners' strike led to a state of emergency and the banning of strikes in September 1978. January 1979 saw a call for a general strike which was only averted when the government lifted constitutional guarantees of civil liberties. The July 1979 miners' strikes resulted in the declaration of a state of emergency and the application of repressive measures by the government.

It may be that Peru possesses significant deposits which could be more fully developed. The information indicated above suggests that this is likely to be a rather risky investment for the foreign investor. On this basis, we would conclude that Peru is unlikely to be a major competitor in the search for investment capital to develop and/or expand its mining activities.

<u>The Philippines</u>

The Philippines is a major producer of nickel and gold.

The current political situation in the Philippines is not a good one. One Hong Kong banker states that " in terms of the political and social situation, the Philippines is the most volatile country in south east Asia".[65]

This statement is supported by evidence of increased violence inside the country in 1980. The bribery and intimidation tactics used by President Marcos during the January 1980 local elections, were condemned strongly by opponents. In February, four opposition political groups united to attempt to overthrow President Marcos and his martial law rule. Moslem guerillas were active in Mindanao cities and were responsible for several bombings and killings in the area in February and March. The government arrested a large number of freedom marchers on July 4, 1980. In October an international travel agents' conference in Manila was bombed by terrorists.

The economic picture is not much more reassuring. The Banker reports that external debt has reached $9 billion by 1979 and that inflation was reaching levels of 16-17% by the end of 1979.[66] A Union Bank survey which was released on February 12, 1980, indicates that a worker in Manila would have to work for 500 hours to purchase the same goods as those purchased by a worker in Chicago after 82 working hours.

The five indices which report on both Canada and the Philippines all agree that the Philippines is a less secure investment area than Canada. The Frost and Sullivan risk fore-

cast describes the Philippines as a high risk country.[67]

Given this evidence, it appears to be logical to conclude that the Philippines will not be a major competitor of Canada in the search for investment capital in the near future.

Republic of South Africa

South Africa is a major producer of gold, iron ore, nickel and platinum.

If economic indicators alone meant anything, then one would have to conclude that South Africa is an excellent place in which to invest. Its Minister of Finance has predicted in his 1980 budget a real growth rate of six percent. In the same document, the Minister notes that governmental income exceeded predicted levels by twenty percent in the preceeding year because of the unexpected increase in the price of gold.

F.T. Haner, the creator of the BERI index comes to very different conclusions. He feels that the internal political and social conditions which reflect and result from racial discrimination policies make the future of South Africa very difficult to predict. He rates South Africa as a high risk investment.[68] Although he revises his first quarter (1980) report, Haner still places South Africa six positions lower than Canada in terms of investment risk.[69]

Even Herman Nickel who argues that there is a case to be made for investment in South Africa, agrees that the " U.S.

investment is a needed force for peaceful change - but its long-term future inevitably depends on how much change the Afrikaner government allows".[70] Given the recent labour troubles which Ford and other American firms have experienced in South Africa, and the continuing repression of the black population by the South African government, the risk appears to be greater than Nickel felt it might be.

From this perspective, it appears probable that South Africa will continue to be viewed as a greater investment risk than Canada.

Sweden

Sweden is a major producer of iron ore, silver and zinc.

Sweden is one of the most politically stable countries in the world. In recent years it has experienced a transition from a democratic socialist government to a liberal democratic coalition government. In terms of foreign policy, Sweden pursues a non-aligned course and her territorial integrity is not threatened by outsiders.

From an economic perspective, the image of Sweden is more mixed. On the one hand, the country appears to be quite wealthy. A Union Bank (Zurich) report indicates that in terms of GNP per capita in 1978, Sweden ranked fourth in the world-four steps ahead of the U.S.A. On the other hand, many economists are pointing to weaknesses in the Swedish economy. The budget for the 1981 fiscal year, for example, projects a deficit

of $13.4 billion.

The Economist indicates four major areas of concern:

> The country's reputation for quality (which used to help sustain high wages) is now matched or nearly matched, by other countries.
> Real rates of investment have dropped.
> Productivity growth has been falling since the mid-1960s.
> Experiments in improved working conditions have failed to stop excessive absenteeism, now running at 20% in many companies.
> Over 40% of exports are accounted for by forest products, shipbuilding, steel and textiles, industries in which it is hard for Sweden's high-wage economy to compete with newly industrialized countries.[71]

The Swedes hope that by concentrating their efforts on high technology, they can improve their economic outlook.

One important fact of life is the Swedish economy is the influence of unions. In the 1970's there has developed " an overt polarisation between employers and unions" .[72]

In policy terms this is reflected in the co-determination law which went into effect in 1977 and which requires that company decisions be discussed with the labour force at the local level before implementation. More recently, in terms of industrial relations, the union influence has been felt during a strike of some 926,000 workers during several weeks in the spring of 1980.

One of the 5 indices which provide comparative rankings for Canada and Sweden, only one, the Euromoney 1980 survey, gives Sweden a higher ranking than Canada.[73]

Although Canada may be somewhat more attractive to

potential investors, it is probable that Sweden will continue to be a strong competitor in the search for mineral development investment funds.

U.S.A.

The U.S. is a major producer of copper, gold, iron ore, lead, silver platinum, and zinc.

The U.S. remains as one of the most attractive investment areas. BERI rates it three positions above Canada.[74]

The major difficulty involves the depletion of high yield reserves. Considerable exploration is likely to be required at great expense.

Mr. Reagan's budget has been viewed favourably by most industries. His tax cuts were made to stimulate investment and spending. His relaxation of environmental controls has received considerable support from mining companies, particularly those involved in development and mining of coal.

In addition, many U.S. lobbyists and politicians have expressed concern about the Canadian governments recent efforts to " Canadianize" sectors of our economy. Indeed one influential lobbyist, James Miller, has argued recently that " the reliability of traditionally friendly Canada as a long term source of strategic minerals for America must be questioned" .[75] It is not yet clear whether the budget presented by Mr. Mac Eachern is sufficient to allay such U.S. concerns about Canadian economic policy.

Although Canada does possess some resource advantages, it seems to be accepted by most experts that the U.S. will continue to be viewed as a better investment risk in the near future.

Rhodesia (Zimbabwe)

Zimbabwe is a mjor producer of nickel and gold.

The initial success of Mr. Robert Mugabe in achieving majority support provided an optimistic note for the future of the country. In recent months this optimism has given way to a heightening concern about at number of problems which threaten the political and economic sectors of the state.

Although the country has a reasonably well developed infra-structure and an efficient administration, the economy suffered drastically from the ravages of war. Enormous amorants of capital will be needed and this has not been forthcoming. The U.S. has promised $15 million in aid. The United Kingdom has developed an aid package of $165 million over the 1981-1983 period. The Banker suggests that $1.5 billion is needed if "Zimbabwe is going to resettle the people displaced by the war, rebuild its rural infra-structures and schools and provide irrigated land for settlement...and hope to remain politically stable".[76]

Politically, the cabinet has changed drastically both in terms of its membership and its policies. Mr. Joshua Nkoma, a major political figure within the country has resigned from the government. Guerilla activity within the country has

increased dramatically. The government has become increasingly interventionist in terms of controlling and directing the economy during the past eighteen months.

Only the Institutional Investor rankings provide a basis of comparison between Canada and Zimbabwe. In 1979, Canada is ranked 78 places ahead of Zimbabwe. In 1980 Canada is ranked 75 places ahead of Zimbabwe.

This brief review of investment climates for some of our potential competitors indicates that Canada is viewed as an attractive place in which to invest. Australia, Chile, Sweden and the U.S.A. are likely to compete strongly with Canada for the capital resources needed to develop new mines and mineral processing facilities.

Within Canada, Ontario has to compete with a number of other provinces for mining investment. Newfoundland, New Brunswick, Quebec, Manitoba, Saskatchewan, British Columbia, the Yukon and the North West Territories are important mineral producers.[79] Each of these areas is also searching for new mineral development.

Ontario has been viewed as a secure investment area for a long period of time. It is politically stable; it is not deeply involved witn nationalisation of existing mining companies; it possesses a government which is viewed as being generally sympathetic to the concerns of industry.

One of the factors which is less favourable to Ontario is its taxation of mining operations in the Province. The following example points this out clearly.

In a recent study, Price Waterhouse has calculated the amount of mining tax which would have to be paid by companies earning $3,000 of revenue.[80]

Ontario	$187
Manitoba	$168
Quebec	$177
British Columbia	$156

When federal and provincial income taxes are combined with provincial mining taxes, the picture changes slightly. This example involves a hypothetical new mine over a ten year period with an accounting income of $10,000.[81]

Ontario

	%	% of Accounting Income
Federal Income Tax	2,070	20.70
Ontario Income Tax	867	8.67
Ontario Mining Tax	1,679	16.79
	4,616	46.16

Quebec

Federal Income Tax	2,070	20.70
Quebec Income Tax	690	6.90
Quebec Mining Tax	1,770	17.70
	4,530	45.30

British Columbia

Federal Income Tax	2,070	20.70
B.C. Income Tax	1,313	13.13
B.C. Mining Tax	1,560	15.60
	4,943	49.43

Manitoba

Federal Income Tax	2,070	20.70
Manitoba Income Tax	863	8.63
Manitoba Mining Tax	1,680	16.80
	4,613	46.13

From this perspective, it appears that Ontario's taxation insofar as mining taxes are concerned, is greater than three of its provincial partners in Confederation. When federal and provincial taxation is combined, only British Columbia appears to levy a higher burden of taxation than Ontario. Manitoba and Quebec, in both situations, tax mining companies less. This taxation burden may detract somewhat from Ontario's attractiveness as an area in which to invest in mineral development projects.[82]

On balance, however, Ontario's investment climate appears to be a good one. The Province's political stability and attitude to private investment are positive features which should enable mining companies to attract the capital required to develop potential profitable mineral deposits in the Province in future.

If a demand for additional supply is likely to exist in the international market in the future and if the required capital resources needed to develop additional supply are likely to be available, the question which follows is: what is the probability that these mineral resources exist and will be found in the area North of 50° North in the Province of Ontario. In the following chapter we examine this issue and describe the topography and climate of this vast area.[83]

NOTES

1. C.W. Smithson, G. Anders, W. Gramm and S. Maurice, World Mineral Markets: An Econometric and Simulation Analysis. (Toronto: Ministry of Natural Resources, 1979).

2. See E. Willauer, Forecasting World Mineral Prices, Production and Consumption, Appendix A, pp. 19-20.

3. W. Malenbaum, " Slower Growth Projected for Mining" Engineering and Mining Journal, January 1978, p. 63.

4. See, for example, J.M. West, " Gold" in U.S.B.M., Mineral Facts and Problems, 1975, pp. 439-440.

5. T.P. Mohide, Platinum Group Metals - Ontario and the World. (Toronto: Ministry of Natural Resources, 1979).

6. See E. Willauer, Forecasting World ..., pp. 16, 19, 38-63.

7. Especially in the case of gold. See H. Strauss and E. Willauer, Report on Gold. (Submitted to the Royal Commission on the Northern Environment, May, 1981).

8. See Dr. H. Strauss and Dr. E. Willauer, Report on Platinum. Submitted to the Royal Commission on the Northern Environment, July 1981.

9. See above, Chapter I, pp. 5-6 for more detail. See also individual mineral Reports submitted by Dr. H. Strauss and Dr. E. Willauer.

10. Dr. H. Strauss and Dr. E. Willauer, Report on Gold. Submitted to the Royal Commission on the Northern Environment, May 1981, p. 8.

11. See pp. 38-74 of H. Strauss and E. Willauer, Report on Nickel.

12. See pp. 37-52 of H. Strauss and E. Willauer, Report on Silver.

13. H. Strauss and E. Willauer, Report on Lead. Submitted to the Royal Commission on the Northern Environment, July 1981, p. 18.

14. IBID, pp. 35-52.

15. H. Strauss and E. Willauer, Report on Zinc. Submitted to the Royal Commission on the Northern Environment, July 1981, pp. 26-43.

16. IBID, p. 60.

17. H. Strauss and E. Willauer, Report on Molybdenum. Submitted to the Royal Commission on the Northern Environment, July 1981, pp. 50-51.

18. H. Strauss and E. Willauer, Report on Platinum submitted to the Royal Commission on the Northern Environment, July 1981, p. 50.

19. IBID, p. 74.

20. H. Strauss and E. Willauer, Report on Copper. Submitted to the Royal Commission on the Northern Environment, August 1981, p. 34.

21. IBID, pp. 129-137.

22. H. Strauss and E. Willauer, Report on Iron Ore. Submitted to the Royal Commission on the Northern Environment, September 1981, p. 1.

23. H. Strauss and E. Willauer, Radioactive Fuel Minerals: Uranium and Thorium. Submitted to the Royal Commission on the Northern Environment, October 1981), p. 6.

24. For more detail see H. Strauss and E. Willauer, Report on Nickel, pp. 38-74.

25. For more detail see H. Strauss and E. Willauer, Report on Gold, pp. 32-56.

26. For more detail see H. Strauss and E. Willauer, Report on Silver, pp. 37-52.

27. For more detail see H. Strauss and E. Willauer, Report on Zinc, pp. 26-43.

28. See H. Strauss and E. Willauer, Report on Lead, pp. 35-52, for more detail.

29. See H. Strauss and E. Willauer, Report on Molybdenum, pp. 22-35, for more detail.

30. See H. Strauss and E. Willauer, Report on Platinum, pp. 36-53, for more detail.

31. See H. Strauss and E. Willauer, Report on Copper, pp. 33-116, for more detail.

32. See H. Strauss and E. Willauer, Report on Iron Ore, pp. 33-61, for more detail.

33. See H. Strauss and E. Willauer, Radioactive Fuel Minerals: Uranium and Thorium, pp. 65-102, for more detail.

34. H. Strauss and E. Willauer, Report on Platinum, p. 11.

35. H. Strauss and E. Willauer, Report on Molybdenum, pp. 5-8, 48.

36. H. Strauss and E. Willauer, Report on Lead, pp. 3-4, 63.

37. H. Strauss and E. Willauer, Report on Zinc, pp. 3-4, 56.

38. H. Strauss and E. Willauer, Report on Silver. Submitted to the Royal Commission on the Northern Environment, July 1981, pp. 75-82.

39. H. Strauss and E. Willauer, Report on Nickel, pp. 5-6, 83-91.

40. H. Strauss and E. Willauer, Report on Gold, pp. 98-99.

41. H. Strauss and E. Willauer, Report on Copper, pp. 125-128.

42. H. Strauss and E. Willauer, Report on Iron Ore, p. 79.

43. H. Strauss and E. Willauer, Radioactive Fuel Minerals: Uranium and Thorium, pp. 79-86.

44. See H. Strauss and E. Willauer, Radioactive Fuel Minerals: Uranium and Thorium, pp. 103-119 for more detail.

45. For further elaboration see D. Haendel, G. West and R. Meadow, Overseas Investment and Political Risk.(Philadelphia: Foreign Policy Research Institute, 1975). See also R.V. Segsworth, Political Risk Analysis, a technical report prepared for the Royal Commission on the Northern Environment, October, 1980.

46. See Kates, Peat, Marwick and Co., Foreign Ownership and the Mining Industry. (Toronto: Select Committee on Economic and Cultural Nationalism of the Legislative Assembly of Ontario, 1973).

47. D. Haendel et al., Overseas Investment and Political Risk, p. 63.

48. See Dr. H. Strauss, Reports on individual minerals submitted to the Royal Commission on the Northern Environment, April-May 1981.

49. See Appendix B.

50. " Oh Brazil" , The Economist, August 4, 1979, pp. 5-8.

51. " Fasten Seat Belts" , The Banker, February 1980, p. 18.

52. " Oh Brazil" , op. cit.

53. See Appendix B.

54. Time, January 14, 1980, p. 46.

55. IBID

56. L.Kraar, " The Multi-nationals Get Smarter About Political Risk" , Fortune, March 24, 1980, p. 88.

57. IBID

58. " The Dominican Republic: A Businessmen's Dialogue" , The Nation's Business, September 1979, p. 4.

59. See Appendix B.

60. R.J. Rummel and David Heenan, " How Multi-nationals Analyse Political Risk", Harvard Business Review, January-February 1978.

61. L. Krarr, " The Multi-Nationals ... " , p. 95.

62. " Staying Sheltered" , The Economist, March 22, 1980, p. 70.

63. See Appendix B.

64. J. Sachdev, " Foreign Investment Policies of Developing Hist Nations and Multinationals" , Management International Review, Vol. 18, 1978, p. 38.

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66. IBID, p. 137.

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69. See Appendix B.

70. W. Nickel, " The Case for Doing Business in South Africa" , Fortune, June 19, 1978, p. 60.

71. " Can Technology Revive Sweden's Economy" , The Economist, November 24, 1979, p. 109.

72. W. G. Jones, " Sweden's Sober Dawn" , Management Today, July 1980, p. 70.

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74. See Appendix B.

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77. IBID, p. 54.

78. See Appendix

79. See Chapter I, pp.
and H. Strauss, Technical Information Paper No. 2. Submitted to the Royal Commission on the Northern Environment, April 1981.

80. Price-Waterhouse and Co., Canadian Mining Taxation. (Toronto: September 1979), pp. 18-33.

81. IBID, Appendix A.

82. The issue of taxation is dealt with more fully below. See pp.

83. For more information on Production, Consumption and Price statistics see Table II 1-7, Appendix A. For more elaboration regarding Risk Indices, see Appendix B.

CHAPTER THREE

THE REGION NORTH OF 50°N

Even if external factors which affect the feasibility of mining developments within Ontario are positive, internal considerations may rule out the possibility of new mining ventures coming on stream in the near future. Among these internal factors are terrain and climatic conditions which can increase the costs of mineral development considerably. In addition, one clearly must find mineral deposits which are large and rich enough to allow any mining development at all to occur. It is these basic characteristics of the area which form the focus of this section of our report.

The region north of 50°N in Ontario is enormous. It contains approximately 210,000 square miles of largely uninhabited terrain. At the present time, a number of successful mining ventures operates in parts of the region. On this basis, it appears that the climate and terrain conditions are not major impediments to new mineral development projects in the area. A brief review of these two features may help to provide a basis for such a conclusion.

Terrain

The region is characterised by two major features. These are the Canadian Shield and the Hudson and James Bay Lowlands. From the slightly undulating character of the south west the region gradually slopes to a wide flat plain which ends at the shores of Hudson's Bay and James Bay.

The Canadian Shield constitutes the bedrock of the highlands area and only 11% of the Shield is covered by lakes and rivers. The Lowlands area is comprised primarily of sedimentary rock although there are outcroppings of the Canadian Shield in the Sutton Hills area. Only 3% of the Lowlands are covered by lakes and rivers; however, 80% of this area is covered by boggy wetlands. What this means is that approximately 100,000 square miles of the area north of 50°N is covered by water or wetlands.

Partly because of this, permafrost can be a problem. Fortunately, permafrost areas are relatively scattered throughout the region. Continuous permafrost is found north of the 56th parallel in the west and north of the 55th parallel in the east. There is rather widespread permafrost in the area north of the 55th parallel in the west and the 54.5° parallel in the east. Scattered permafrost exists north of the 53rd parallel in the west and dips to the delta of the Moose River in the east.

With our present knowledge of the geology of the region, we do not expect permafrost to be a major problem for new mining developments in the region. Most of the areas of significant mineral potential are found outside the areas where permafrost is known to exist.

The vegetation of the area changes dramatically as one moves from west to east. The Canadian Shield portion of the study area is comprised primarily of Boreal Forest. The northern portion consists basically of spruce, balsam fir, jackpine and tamarack. The Lowlands are characterized by sedges and sphagnam moss in the boggy areas and by black spruce and tamarack on higher ground. Along Hudson Bay and in the Northern shore of James Bay, we find vegetation more typical of northern Tundra. This includes shrub-like brush and willow, sedges, blueberry, crowberry and Labrador tea.

The environment of the region is viewed as a fragile one and considerable concern regarding the protection of this environment has been expressed during the work of the Commission. Mr. Justice Hart addressed the question of such protection and the environmental assessment process in his Issues Report. Costs related to environmental protection might make marginal ore deposits uneconomic propositions and prevent their development.

Climate

Although the climate of the study area is rather harsh, it does not appear to constitute a major impediment to mineral development ventures, in our view. The effects of rather low temperatures, however, may produce some problems insofar as transportation is concerned.

For most of the area the average annual temperature is below freezing. January, the coldest month, brings average temperatures lower than -18°C. July, the warmest month, reaches an average temperature of over +10°C.

These temperatures vary considerably within the study area and this variability produces some interesting results in terms of ice patterns. Normally, the north-west part of Hudson's Bay is free of ice before the southern part. Both James Bay and Hudson's Bay are free of ice in August and sometimes during the first half of September. Because of this pattern of break-up and ice flow conditions, the shipping season is a relatively short one. The short season may force mining companies to seek alternative transportation modes at greater cost.

Precipitation increases as one moves from the northwest towards the southeast. Annual rainfall varies between 50 cm to over 80 cm. July, August and September are the wettest months of the year.

Snowfall also varies tremendously within our study area. At Winisk an average of 157 cm of snow falls each year.

The average at Pagwa is 337 cms. Normally, the study area is snow-covered from the end of November until April or May.

In general, we do not feel that the climate imposes severe restraints on potential mineral developments. Several mines are currently operating in the area. Many mines operate in other parts of Canada where the extremes of temperature are more severe. The B.C. coast and Atlantic Canada traditionally experience more precipitation than the study area and new mining developments are coming on stream in both of these parts of the country.

In essence, the geographic features of the study area pose some, but relatively minor, difficulties insofar as potential mining developments are concerned. What is a more important consideration is the issue of whether or not significant mineral deposits worthy of development exist and are likely to be found in this part of the province. This question forms the basis of the following section.

Geological Investigation

Even if the terrain and climate of the region are not sufficiently harsh to deter or prevent the development of new mines, it is obvious that such development cannot take place unless economic mineral deposits exist and are found. In this section of our report, we focus attention on some fundamental geological issues. These concerns include the probable location

of deposits in the study area, the probability that such deposits will be found, their size and grade, and their place value.

In order to establish answers to such questions, considerable effort had to be expended. Much of the availabe information on the geology of the region has been expressed in a qualitative form. The MAPS project of the Department of Energy, Mines and Resources and the work of the Ontario Geological Survey were examined. Although this work proved to be most helpful, it did not provide the necessary quantative information needed to complete later stages of the project.

Three basic approaches would provide geological data in a quantitative form. These are delphi method techniques, geostatistical analysis, and opinion polls of experienced geologists who are familiar with the study area. Because of the cost and time considerations, the application of Delphi techniques had to be rejected. We were advised by the staff of the Royal Commission that, in their view, the opinion polling approach would be most appropriate for the conduct of this study. In view of this advice, we polled more than thirty experienced geologists during the summer of 1980. Among these geologists were Vice-Presidents of large mining companies who were responsible for their firms' exploration activities, district geologists with the Ministry of Natural Resources and explo-

ration geologists with both large and small companies who normally spend their summers working in this part of the province. These geologists were asked for their opinions regarding the probability of occurrence of the type of mineral deposits, the number of deposits, and the grade and tonnage of such deposits.[2] It is important to point out that the geologists were questionned about mineral deposits which have not yet been discovered and/or proven. Our Report, therefore, concerns itself with the potential for discovery and development of unknown mineral resources and not with the development of known deposits in the region.

The information derived from such interviews was applied to a set of 136 cells within the study area. Each cell was 1° of longitude in length and 1/2° of latitude in width.[3] This basic data was then subjected to a number of statistical techniques in order to provide the following information:[4]

a) The total number of mineral deposits in the cell.

b) The number of deposits of particular minerals in the cell.

c) The average size (tonnage) of specific mineral deposits in the cell.

d) The average grade of the mineral deposit in the cell.

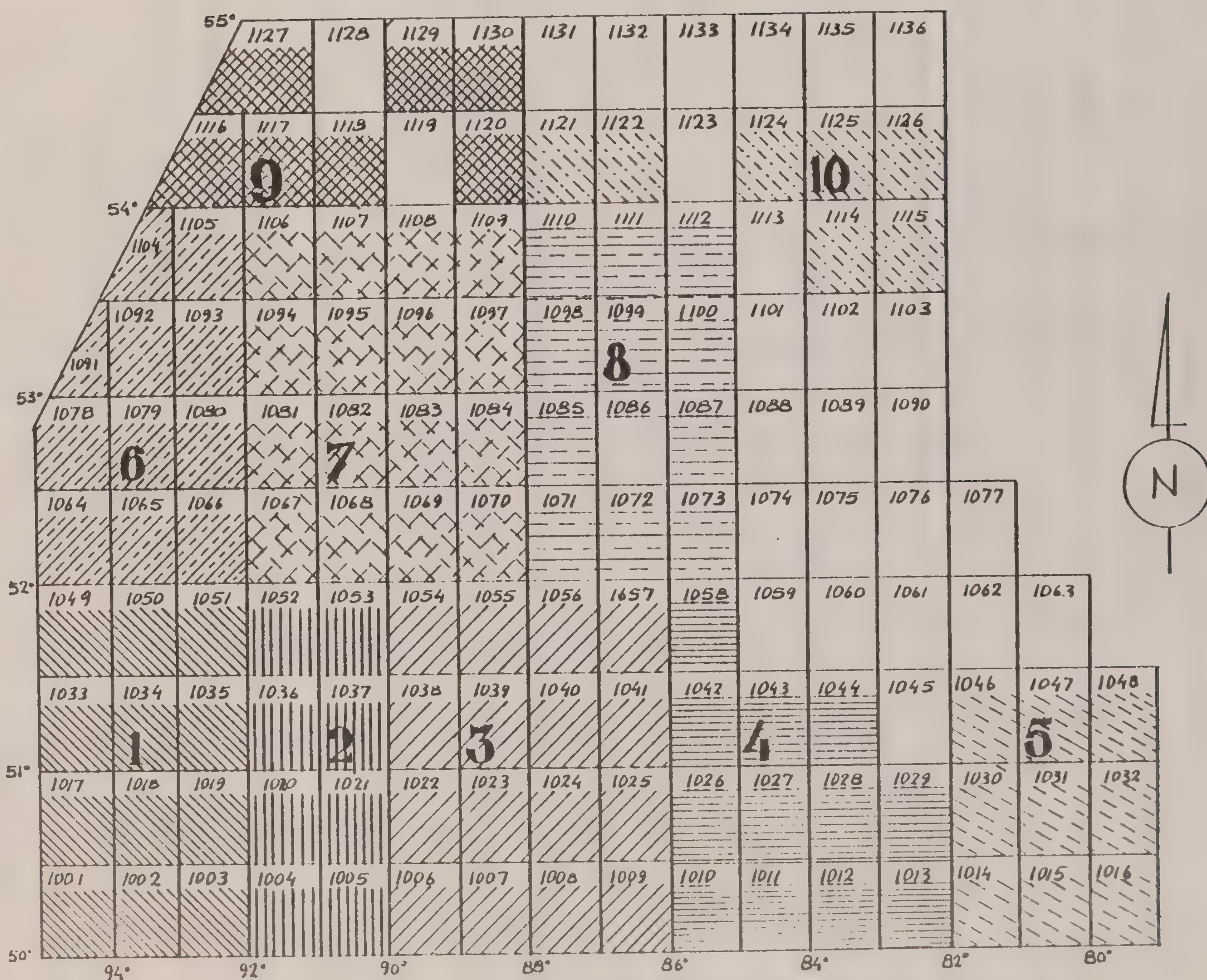
e) The total metal content of the mineral in the cell.

This basic data was analysed for sixteen commodities - copper, zinc, lead, nickel, molybdenum, uranium, gold, silver, iron, lithium and columbium, coal, chronium, diamond, cobalt, and platium. Some of these minerals occurred together. These

combinations such as copper - zinc, lead-zinc, nickel-copper, and copper-lead-zinc were treated as separate categories by the questionnaire. It should also be pointed out that we did not attempt to analyse coal and diamond deposits in as rigorous a fashion as for the other minerals.[5]

One important distinction was used throughout the interviewing process. All sections of the study area North of 52.50°N were classified as remote. The sections South of 52.50°N were classified as accessible because of their relative proximity to existing transportation facilities. As we shall see in the following section, the geologists were much less optimistic about the probability of mineral development in the case of the remote areas than they were for the more accessible regions.

Figure 3 - 1
Division of Study Area



Copper

The data which we received indicates that there may be 24 copper deposits located in 21 cells within the study region. The total metal content of the area is 0.893 million tons of copper. The total place value of the copper is $1.648 billion. These deposits range in size from 0.015 (Cell 1022) to 0.338 (Cell 1021) million tons of metal in place. The grade of these deposits ranges from 2.0 percent (Cells 1006, 1022, 1023), to 4.5 percent (Cells 1009, 1012, 1016, 1017, 1020, 1021, 1032, 1033, 1034, 1036, 1053, 1054, 1055, 1079, 1080, 1093, 1094).

Estimates of the probability that such occurences exist range from 10 to 60 percent. Generally speaking, the geologists interviewed tended to assign higher probabilities of existence to the larger, richer and more accessible deposits than for others. Estimates of the probability of development of these deposits range from 0 to 20 percent for remote areas and 20 to 75 percent for accessible areas.

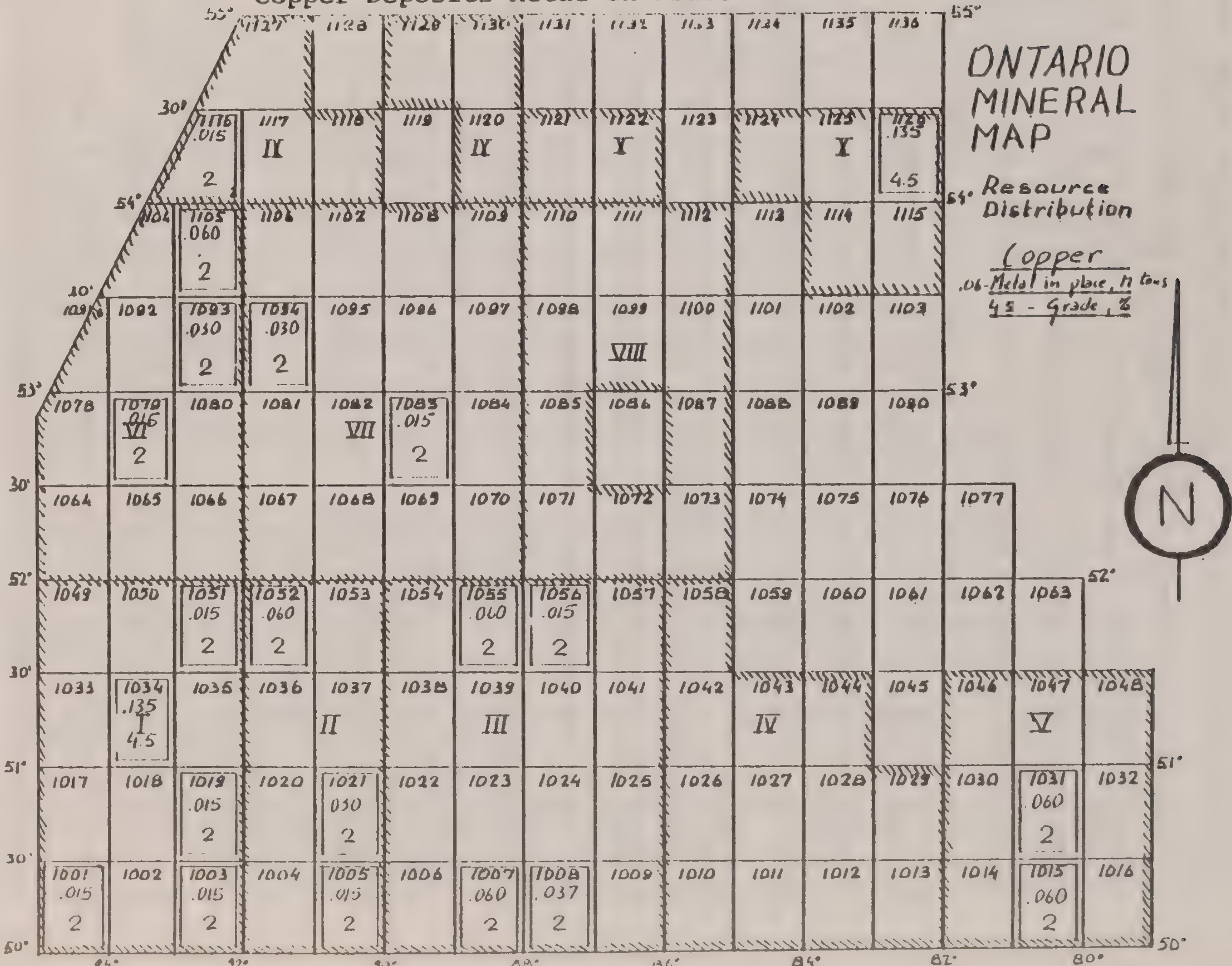
The geologists' assessments insofar as the discovery and development of copper deposits are concerned are quite pessimistic. For the remote areas, they assign a probability range of 0 to 12%. For the more accessible areas, the probability that such deposits exist and will be developed ranges from 2 to 45%.

Copper-Zinc

The data indicates that there may be about 42 copper-

Figure 3 - 2

Copper Deposits Metal in Place and Grade



zinc deposits located in 31 cells within the study region. The total metal content of the area is 7.329 million tons of copper-zinc. The total place value of the copper-zinc is $8.156 billion. These deposits range in size from 0.15 (Cell 1022) to 0.675 (Cell 1012) million tons of metal in place. The grade of these deposits ranges from 2.0 percent (Cells 1006, 1022, 1023), to 4.5 percent (Cells 1009, 1012, 1016, 1017, 1020, 1021, 1032, 1033, 1034, 1036, 1053, 1054, 1055, 1079, 1080, 1093, 1094).

Estimates of the probability that such occurences exist range from 20 to 50 percent. Estimates of the probability of development of these deposits range from 2 to 5 percent for remote areas and 10 to 75 percent for accessible areas.

The geologists' assessments insofar as the discovery and development of copper-zinc deposits are concerned also pessimistic. For the remote areas, they assign a probability range of 0.4 to 2.5%. For the more accessible areas, the probability that such deposits exist and will be developed ranges from 2 to 37.5 percent.

Lead-Zinc-Copper

The geologists' opinions indicate that there may be about 102 lead-zinc-copper deposits located in 87 cells within the study region. The total metal content of the area is 33.43 million tons of lead-zinc-copper. The total place value of the lead-zinc copper is $32.1 billion. These deposits range in size from 0.045 (Cells 1009, 1049, 1050, 1064, 1078) to 1.8 (Cell 1034) million tons of metal in place. The grade of these deposits ranges from 6.0

Figure 3 - 3

Copper-Zinc Deposits Metal in Place and Grade

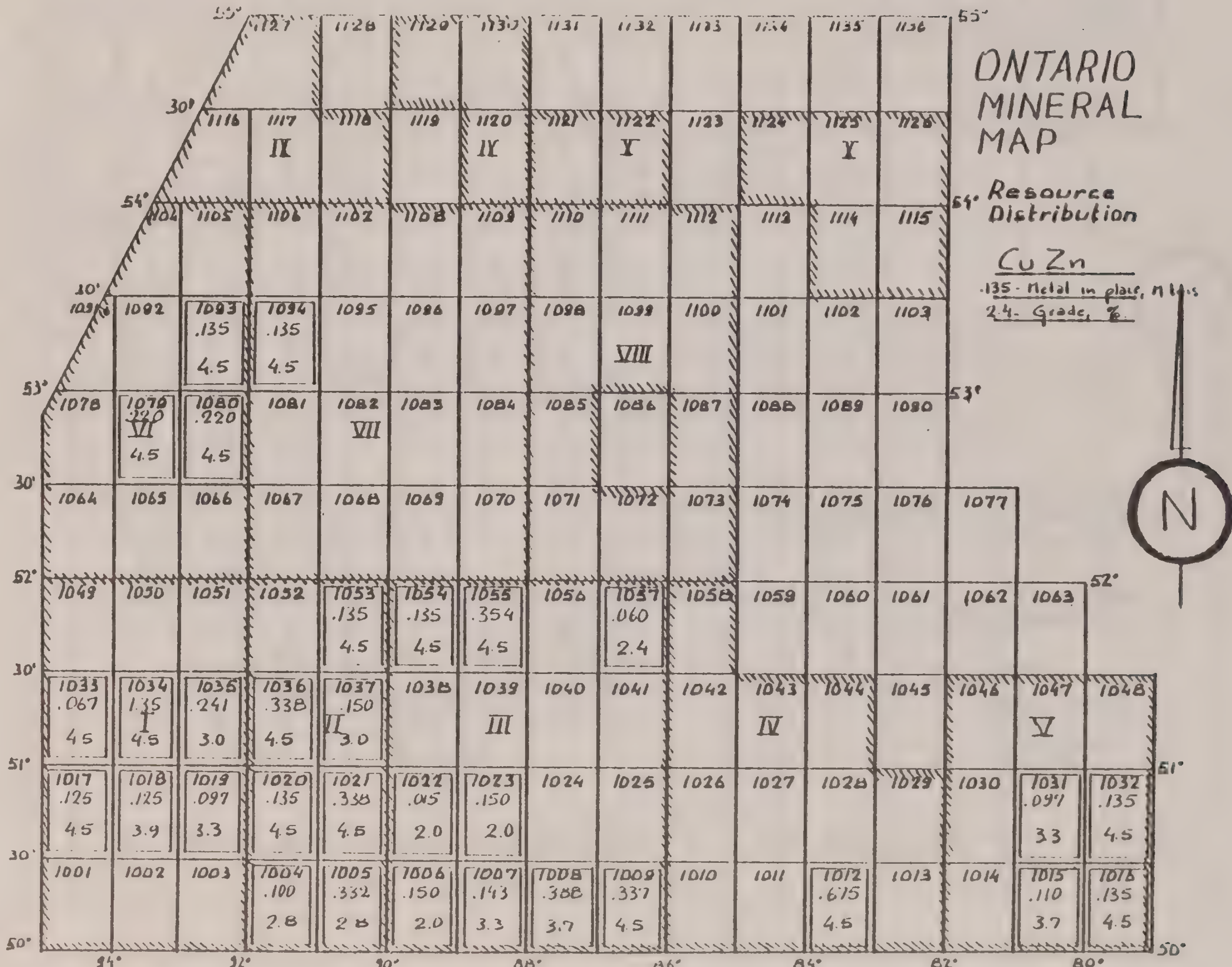
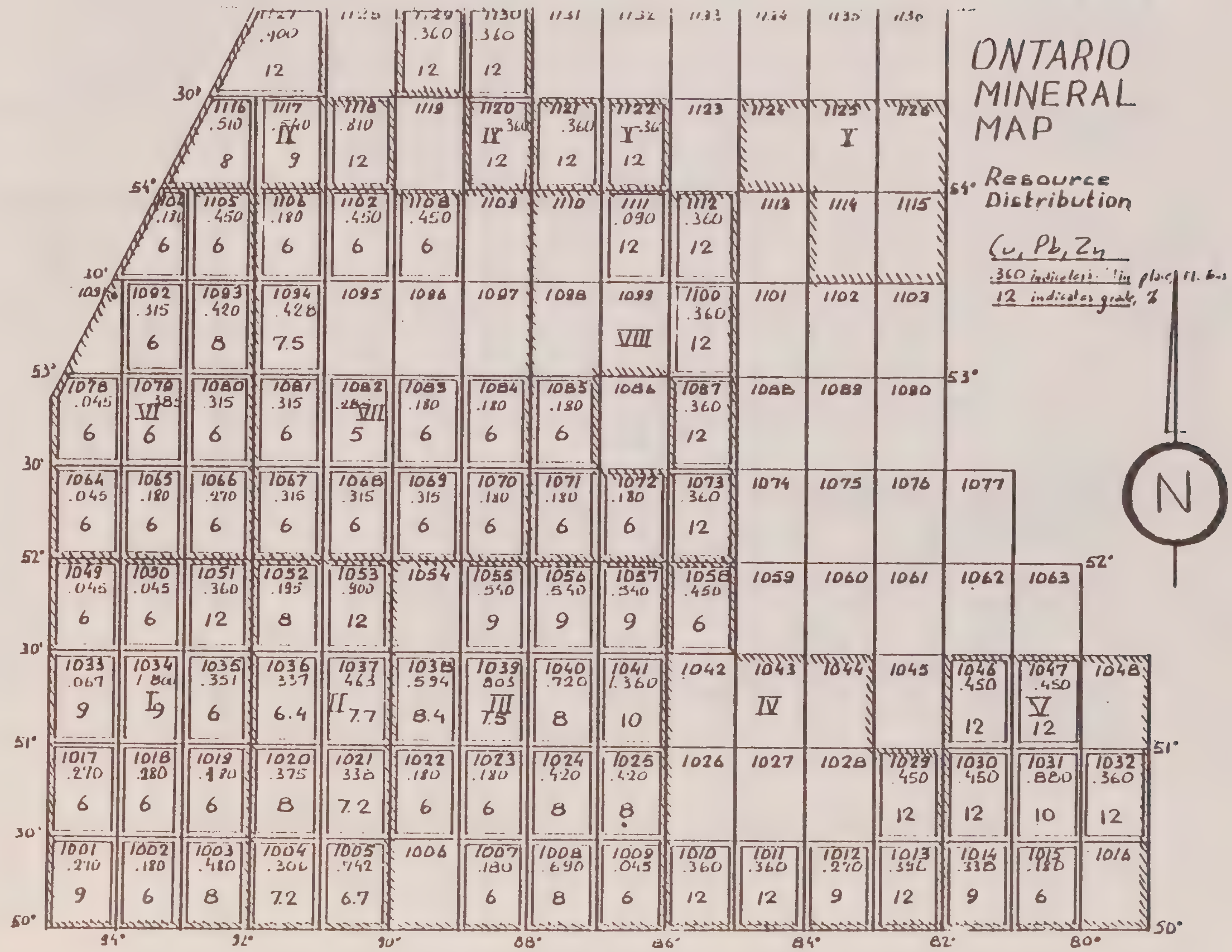


Figure 3 - 4

Copper-Lead-Zinc Deposits Metal in Place and Grade



percent (Cells 1002, 1007, 1009, 1015, 1017, 1018, 1019, 1022, 1023, 1035, 1049, 1050, 1058, 1064-1072, 1078-81, 1083-85, 1092, 1104-1108) to 12 percent (Cells 1010, 1011, 1013, 1029, 1030, 1032, 1046, 1047, 1051, 1053, 1073, 1087, 1100, 1111, 1112, 1118, 1120-1122, 1127, 1129, 1130).

Estimates of the probability that such occurences exist range from 50 to 100 percent. Estimates of the probability of development of these deposits are 0 percent for remote areas and range from 25 to 100 percent for accessible areas.

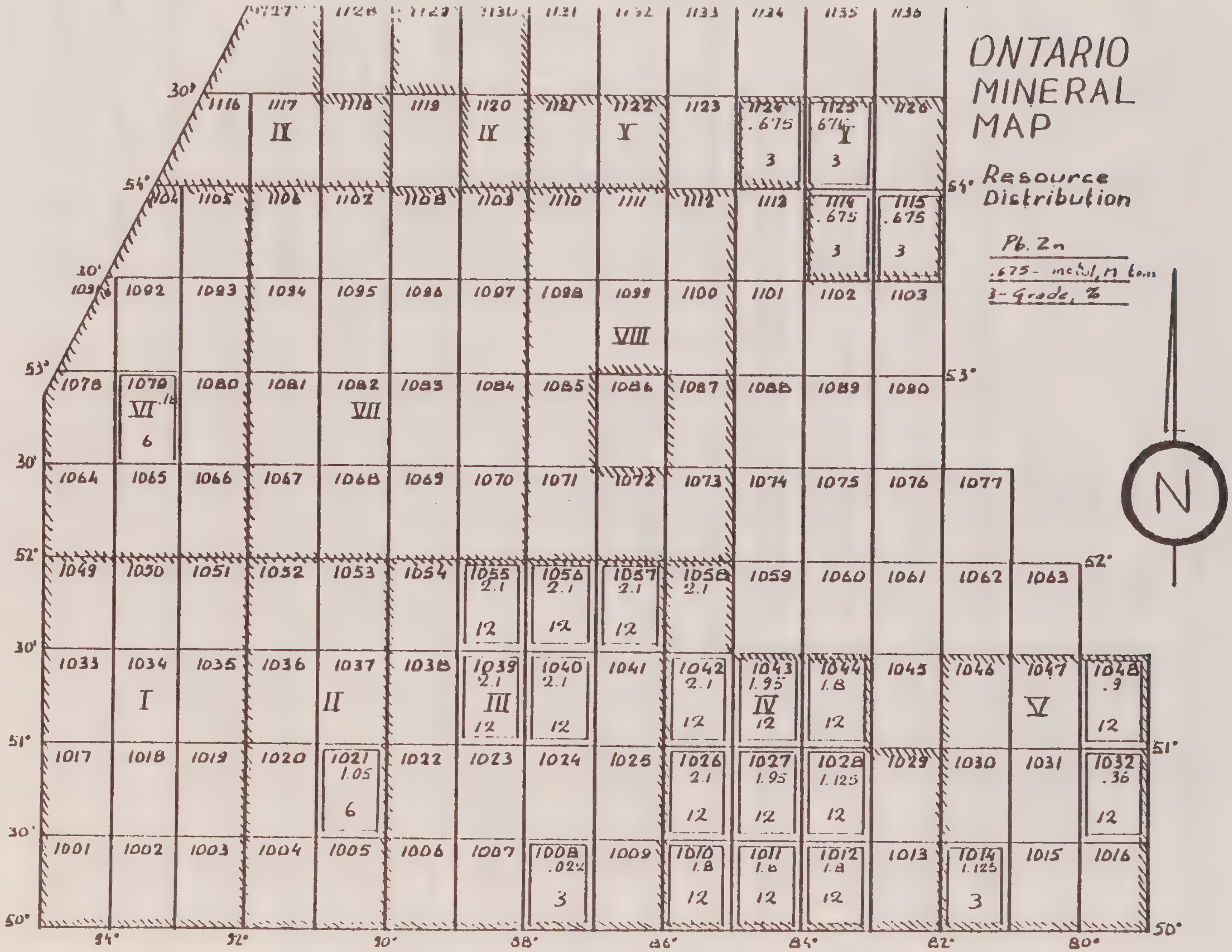
The geologists' assessments insofar as the discovery and development of lead-zinc-copper deposits are concerned are varied. For the remote areas they assign a probability of 0 percent. For the more accessible regions, the probability that such deposits exist and will be developed ranges from 12.5 to 100%.

Lead-Zinc

The data suggests that there may be about 38 lead-zinc deposits located in 24 cells within the study region. The total metal content of the area is 33.262 million tons of lead-zinc . The total place value of the lead-zinc is $29.916 billion. These deposits range in size from 0.022 (Cell 1008) to 2.1 (Cells 1026, 1039, 1040, 1042, 1055-1058) million tons of metal in place. The grade of these deposits ranges from 3.0 percent (Cells 1008, 1014, 1114, 1115, 1124, 1125) to 12.0 percent (Cells

Figure 3-5

Lead-Zinc Deposits Metal in Place and Grade



1010-1012, 1026-1028, 1032, 1039, 1040, 1042-1044, 1048, 1055-57).

Estimates of the probability that such occurences exist range from 25 to 50 percent. Estimates of the probability of development of these deposits range from 0 to 10% for remote areas and from 50 to 100% for accessible areas.

The geologists' assessments insofar as the existence and development of lead-zinc deposits are concerned are somewhat pessimistic. For the remote areas they assign a probability range of 0 to 5 percent. For the more accessible regions, the probability that such deposits exist and will be developed ranges from 12.5% to 50%.

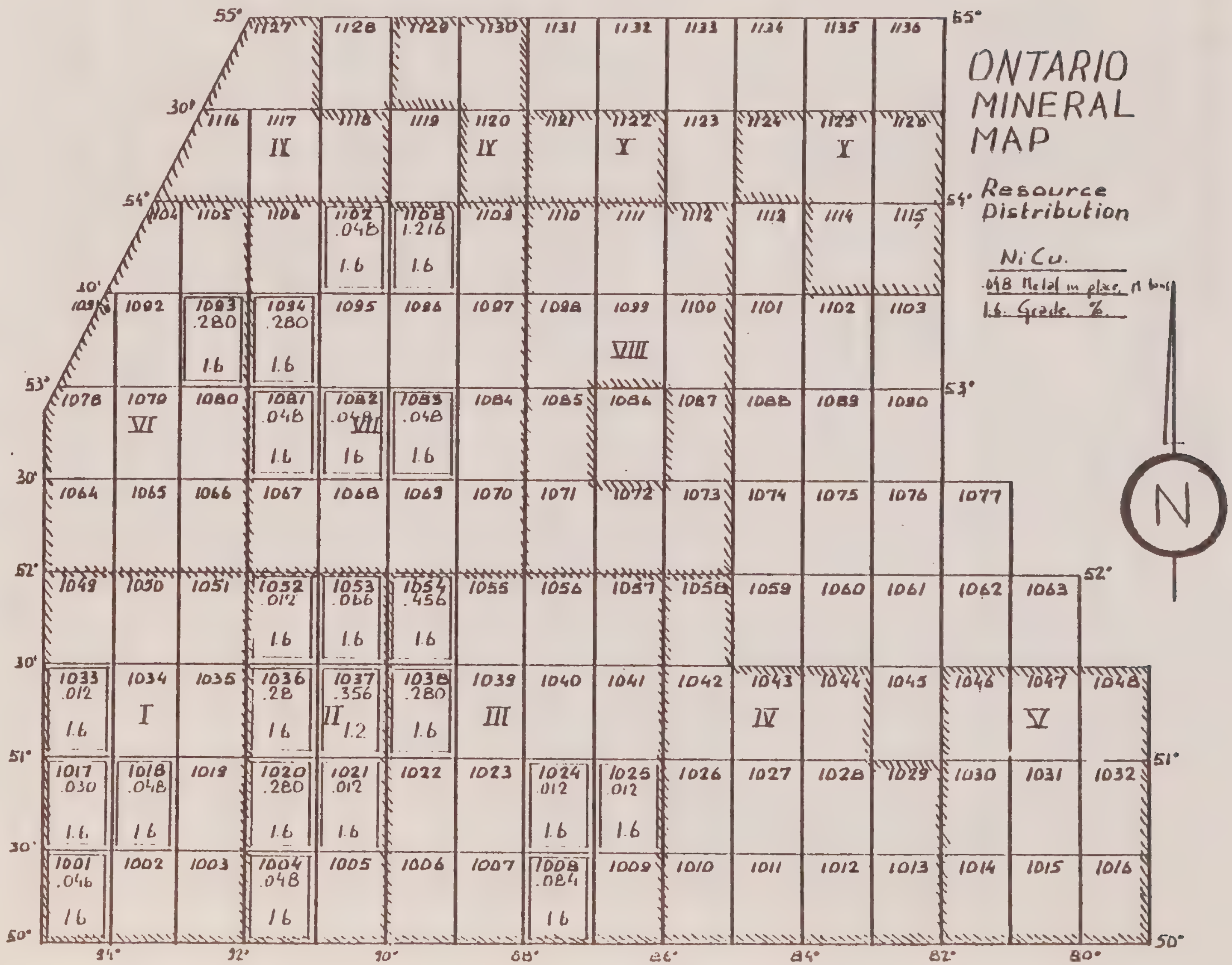
Nickel-Copper

The geological opinions indicate that there may be about 24 nickel-copper deposits located in 23 cells within the study region. The total metal content of the area is 4.001 million tons of nickel-copper. The total place value of the nickel-copper is $16.949 billion. These deposits vary in size from 0.012 (Cells, 1021, 1024, 1025, 1033, 1052) to 1.216 (Cell 1108) million tons of metal in place. The grade of these deposits ranges from 1.2 percent (Cell 1037) to 1.6 percent (Cells 1001, 1004, 1008, 1017, 1018, 1020, 1021, 1024, 1025, 1033, 1036, 1038, 1052-1054, 1081-1083, 1093, 1094, 1102, 1108).

Estimates of the probability that such occurences exist range from 50 to 100 percent. Estimates of the probability of development of these deposits range from 0 to 10% for remote areas and 20 to 60% for accessible areas.

Figure 3 - 6

Nickel-Copper Deposits Metal in Place and Grade



The geologists' assessment insofar as the existence and development of nickel-copper deposits are concerned are rather varied For the remote areas, they assign a probability range of 0 to 10 percent. For the more accessible regions, the probability that such deposits exist and will be developed ranges from 10% to 60%.

Molybdenum

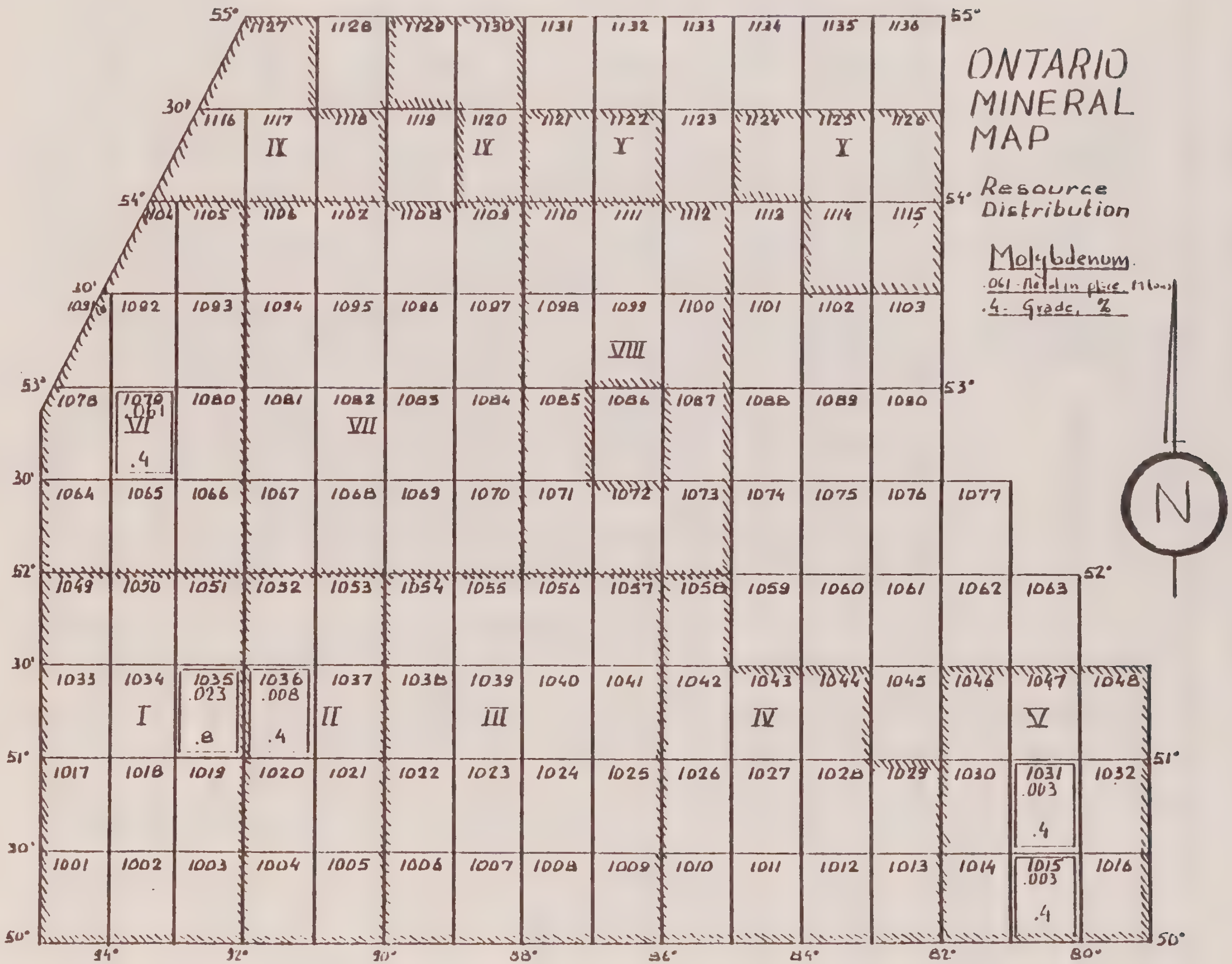
The geologists suggest that there may be about 7 molybdenum deposits located in 5 cells within the study region. The total metal content of the area is 0.097 million tons of molybdenum. The total place value of the molybdenum is $1.188 billion. These deposits vary in size from 0.003 (Cells 1015, 1031) to 0.061 (Cell 1079) million tons of metal in place. The grade of these deposits ranges from 0.4 percent (Cells 1015, 1031, 1036, 1061) to 0.8 percent (Cell 1035).

Estimates of the probability that such occurences exist range from 5 to 15 percent. Estimates of the probability of development of these deposits range from 0 to 2 percent for remote areas and 2 to 20 percent for accessible areas.

The geologists' assessments insofar as the existence and development of molybdenum deposits are concerned are quite pessimistic. For the remote areas, they assign a probability range of 0 to 0.1%. For the more accessible regions, the probability that such deposits exist and will be developed ranges from 0.1% to 3%.

Figure 3 - 7

Molybdenum Deposits Metal in Place and Grade



Uranium

The data indicates that there may be about 24 uranium deposits located in 19 cells within the study region. The total yellow cake content of the area is 599.5 million pounds. The total place value of the uranium is $25.521 billion. The deposits vary in size from 5.25 (Cells 1001, 1091) to 76.563 (Cell 1036) million pounds of yellow cake in place. The grade of these deposits ranges from 1.75 pounds per ton (Cells 1001, 1014, 1017, 1031, 1083, 1084, 1091, 1097, 1118, 1127) to 4.37 pounds per ton (Cell 1036).

Estimates of the probability that such occurences exist range from 10 to 75 percent. Estimates of the probability of development of these deposits vary from 0 to 15% for remote areas and 0 to 70% for accessible areas.

The geologists' assessments insofar as the existence and development of uranium deposits are concerned are extremely varied. For the remote areas, they assign a probability range of 0 to 11.3%. For the more accessible regions, the probability that such deposits exist and will be developed ranges from 0 to 52.5%.

Gold

Our geological investigation indicates that there may be about 87 gold deposits located in 73 cells within the study region. The total gold content of the area is 36.675 million ounces. The total place value of the gold is $11.263 billion. The deposits vary in size from 0.122 (Cell 1083) to 6.0 (Cell 1016) million ounces in place. The grade of

Figure 3 - 8

Uranium Deposits Metal in Place and Grade

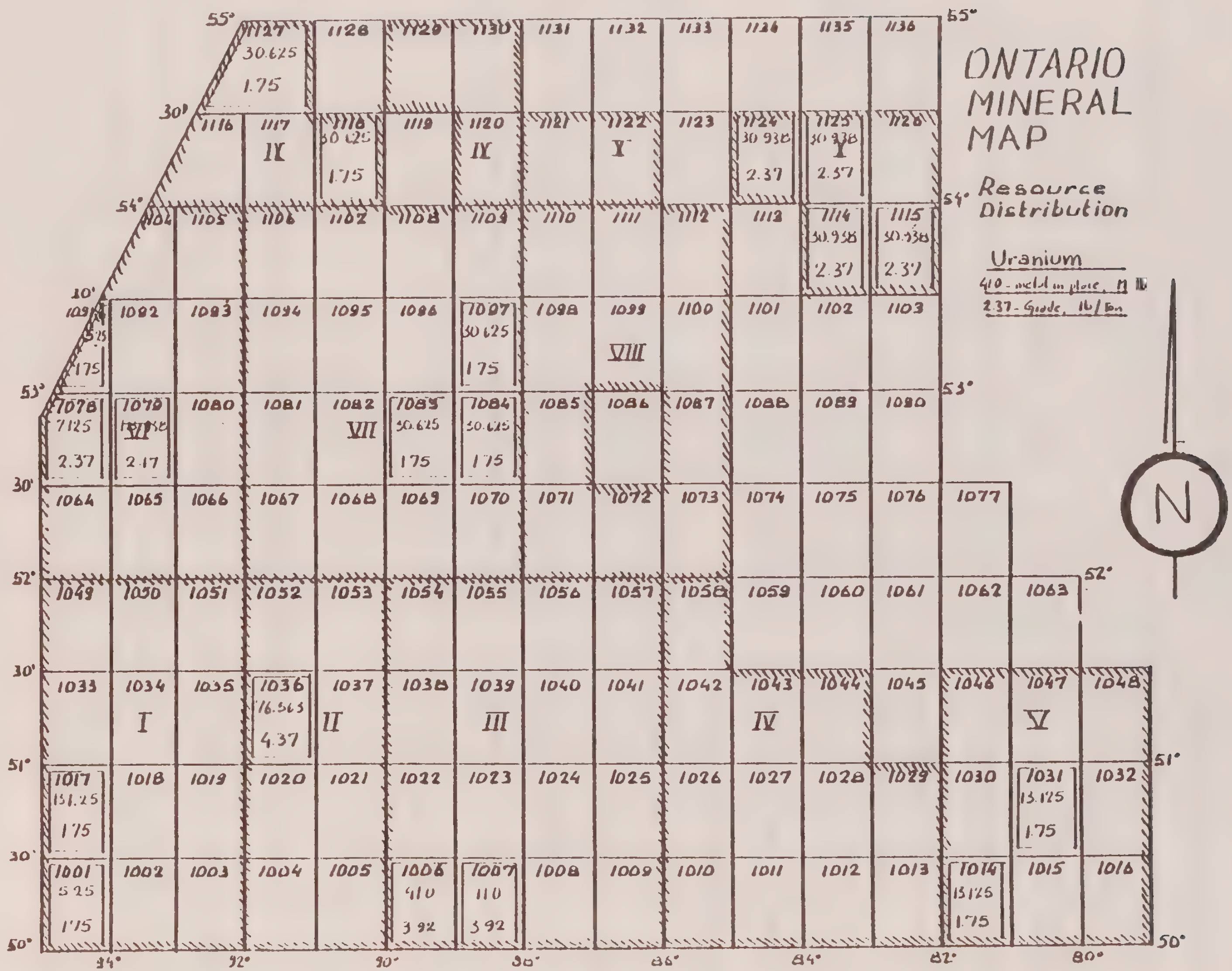
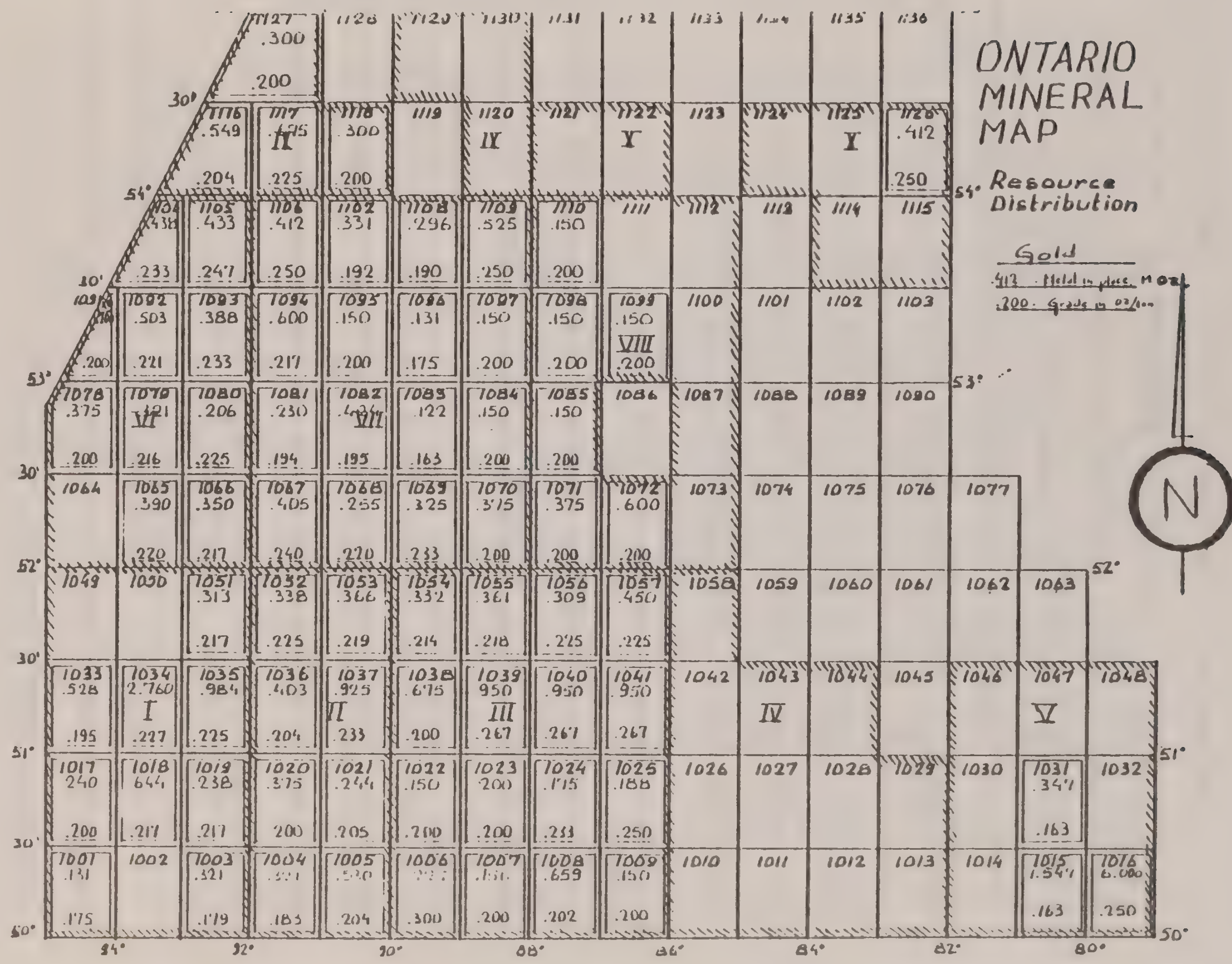


Figure 3 - 9

Gold Deposits Metal in Place and Grade



these deposits ranges from 0.163 ounces per ton (Cells 1015, 1031, 1083) to 0.267 ounces per ton (Cells 1039-1041).

Estimates of the probability that such occurences exist range from 20 to 30 percent. Estimates of the probability of development of these deposits vary from 20 to 30 percent for remote areas and 35 to 100 percent for accessible areas.

The geologists' assessments insofar as the existence and development of gold deposits are concerned indicate considerable divergence of opinion. For the remote areas, they assign a probability range of 4 percent to 24 percent. For the more accessible regions, the probability that such deposits exist and will be developed ranges from 6 percent to 80 percent.

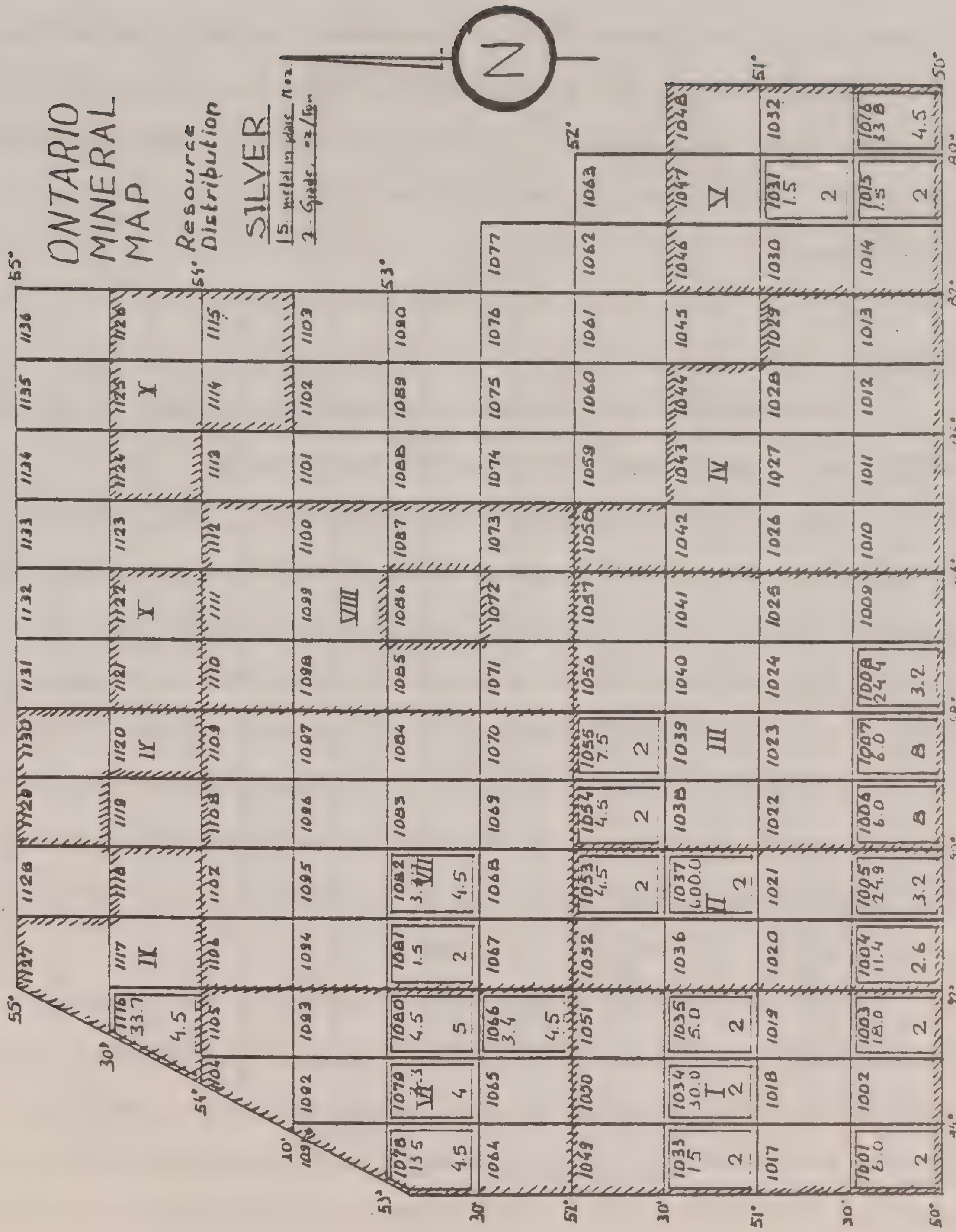
Silver

The data indicates that there may be about 47 silver deposits located in 24 cells within the study area. The total content of the area is 849.8 million ounces of silver. The total place value of the silver is $9.424 billion. The deposits vary in size from 1.5 (Cells 1015, 1031, 1081) to 600 (Cell 1037) ounces of silver in place. The grade of these deposits ranges from 2.0 ounces per ton (Cells 1001, 1003, 1015, 1031, 1033-1035, 1037, 1053-1055, 1081) to 8 ounces per ton (Cells 1006, 1007).

Estimates of the probability that such occurences exist range from 50 to 100 percent. Estimates of the probability of development of these deposits vary from 30 to 80 percent for remote

Figure 3 - 10

Silver Deposits Metal in Place and Grade



areas and 35 to 100% for accessible areas.

The geologists' assessments insofar as the existence and development of silver deposits are concerned are more optimistic than for most minerals. For remote areas, they assign a probability range of 15 to 80%. For the more accessible regions, the probability that such deposits exist and will be developed ranges from 17.5 to 100 percent.

Iron

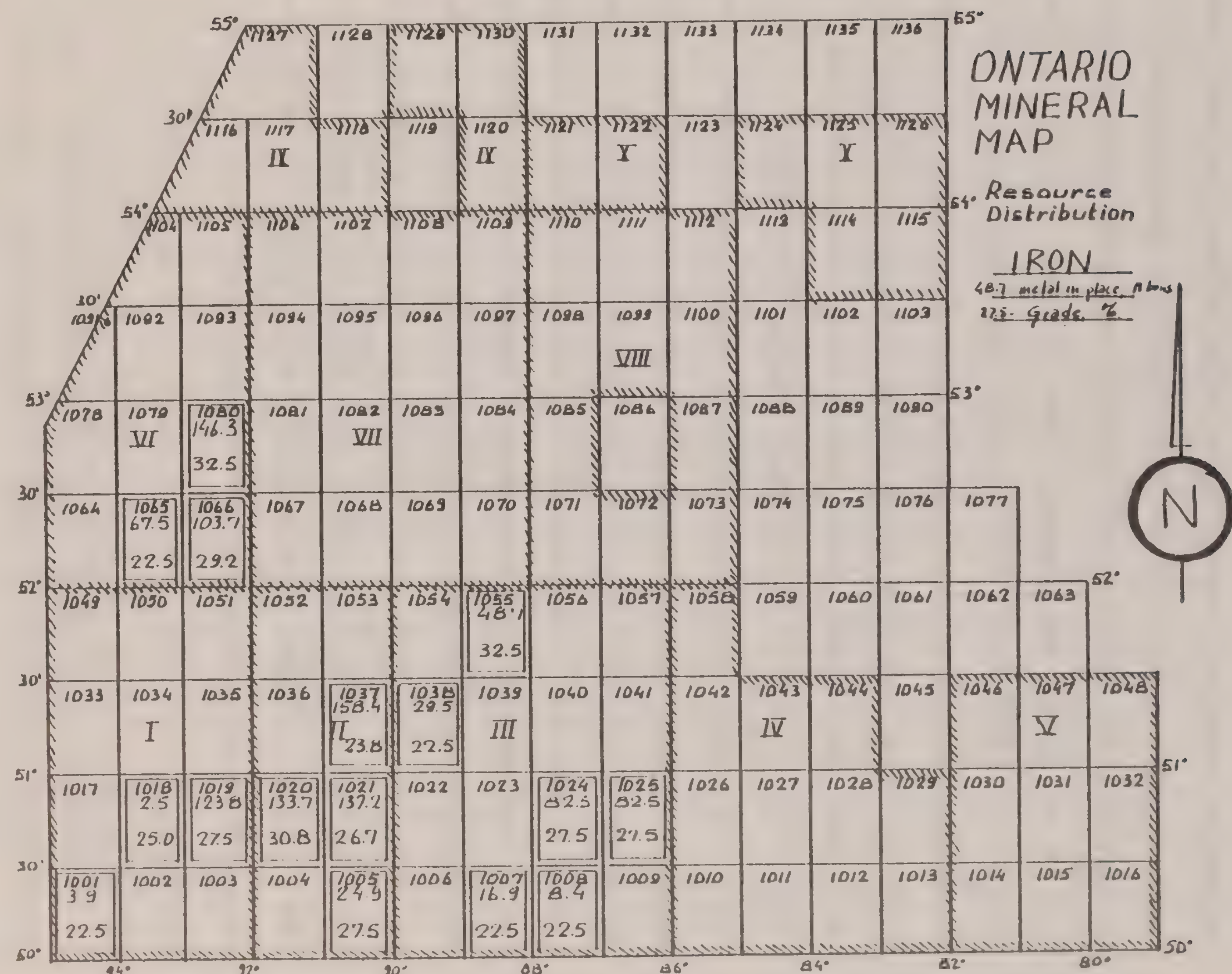
The geological data indicates that there may be about 34 iron deposits located in 16 cells within the study area. The total metal content of the area is 1.223 billion tons of iron. The total place value of the iron is $76.861 billion. The deposits vary in size from 2.5 (Cell 1018) to 158.4 (Cell 1037) million tons of iron in place. The grade of these deposits ranges from 22.5 percent (Cells 1001, 1007, 1008, 1038, 1065) to 32.5 percent (Cells 1055, 1080).

Estimates of the probability that such occurences exist range from 70 to 100 percent. Estimates of the probability of development of these deposits vary from 0 to 20 percent for remote areas and 10 to 90 percent for accessible areas.

The geologists' assessments insofar as the existence and development of iron deposits again indicate considerable divergence of opinion. For the remote areas they assign a probability range of 0 to 20 percent. For the more accessible regions, the probability that such deposits exist and will be developed ranges from 7 percent to 90 percent.

Figure 3 - 11

Iron Deposits Metal in Plåce and Grade



Lithium-Columbium

The data suggests that there may be about 26 lithium-columbium deposits located in 24 cells within the study area. The total mineral content of the area is 2.508 million tons of lithium-columbium. The total place value of the lithium-columbium is $13.735 billion. The deposits vary in size from 0.011 (Cells 1001-1003, 1017-1019, 1021, 1049, 1064, 1078, 1081, 1082, 1095, 1106) to 0.563 (Cell 1047) million tons of lithium-columbium in place. The grade of these deposits ranges from 1.5 percent (Cells 1001-1003, 1017-1021, 1047, 1049, 1055, 1064, 1078, 1081-1084, 1095, 1097, 1106, 1118, 1127) to 2.5 percent (Cells 1007, 1014).

Estimates of the probability that such occurences exist range from 10 percent to 75 percent. Estimates of the probability of development of these deposits vary from 0 percent to 15 percent for remote areas and 15 percent to 60 percent for accessible areas.

The geologists' assessments insofar as the existence and development of lithium-columbium deposits are concerned are generally pessimistic. For the remote areas they assign a probability range of 0 percent to 11.3 percent. For the more accessible regions, the probability that such deposits exist and will be developed ranges from 1.5 percent to 45 percent.

Coal

Geological opinion indicates that there may be about 6 coal deposits located in 6 cells within the study area. The total coal content of the area is 155.725 million tons. The total place value of the coal is $6.229 billion. The deposits vary in size from 0.6

Figure 3 - 12

Lithium-Columbium Deposits Metal in Place and Grade

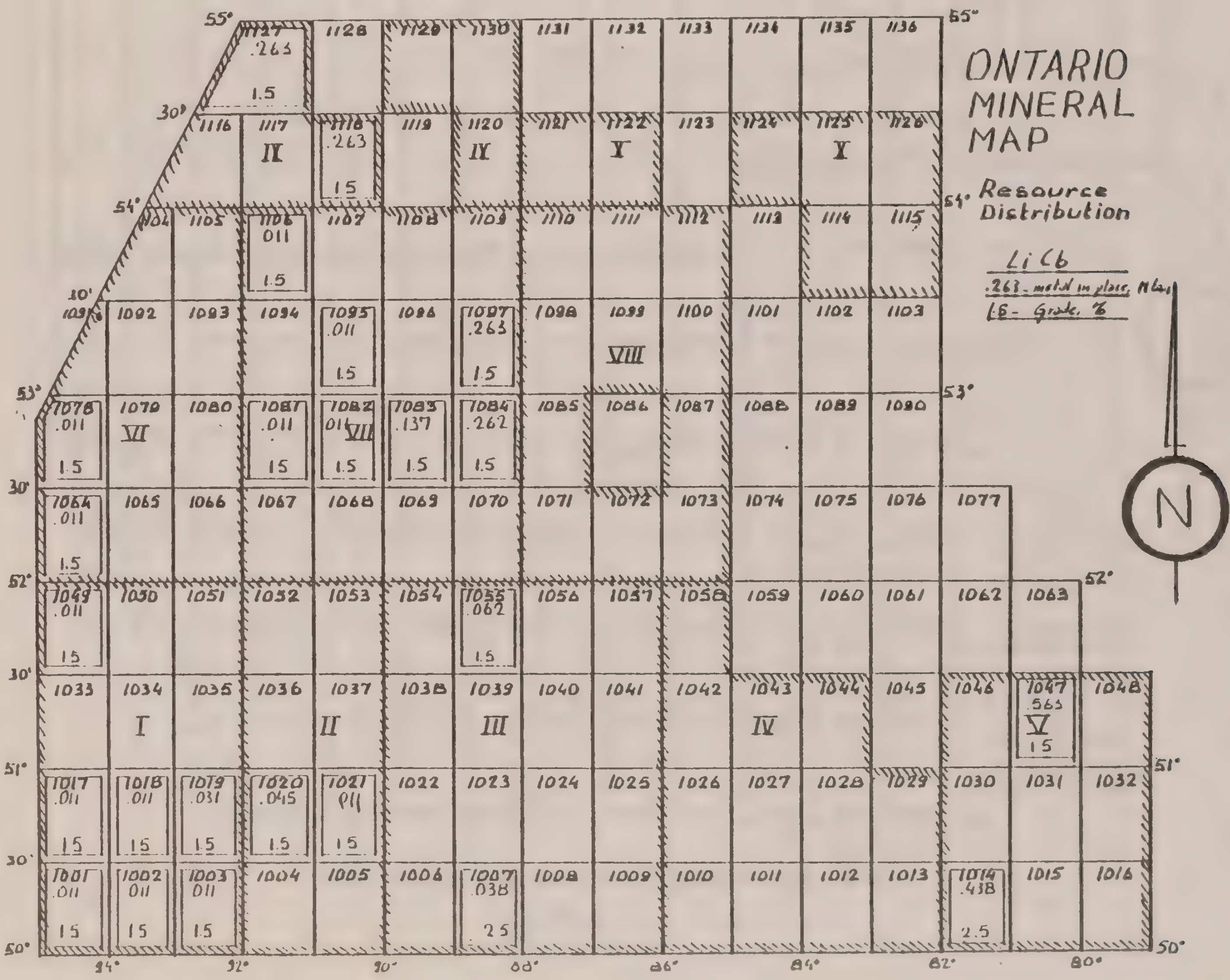
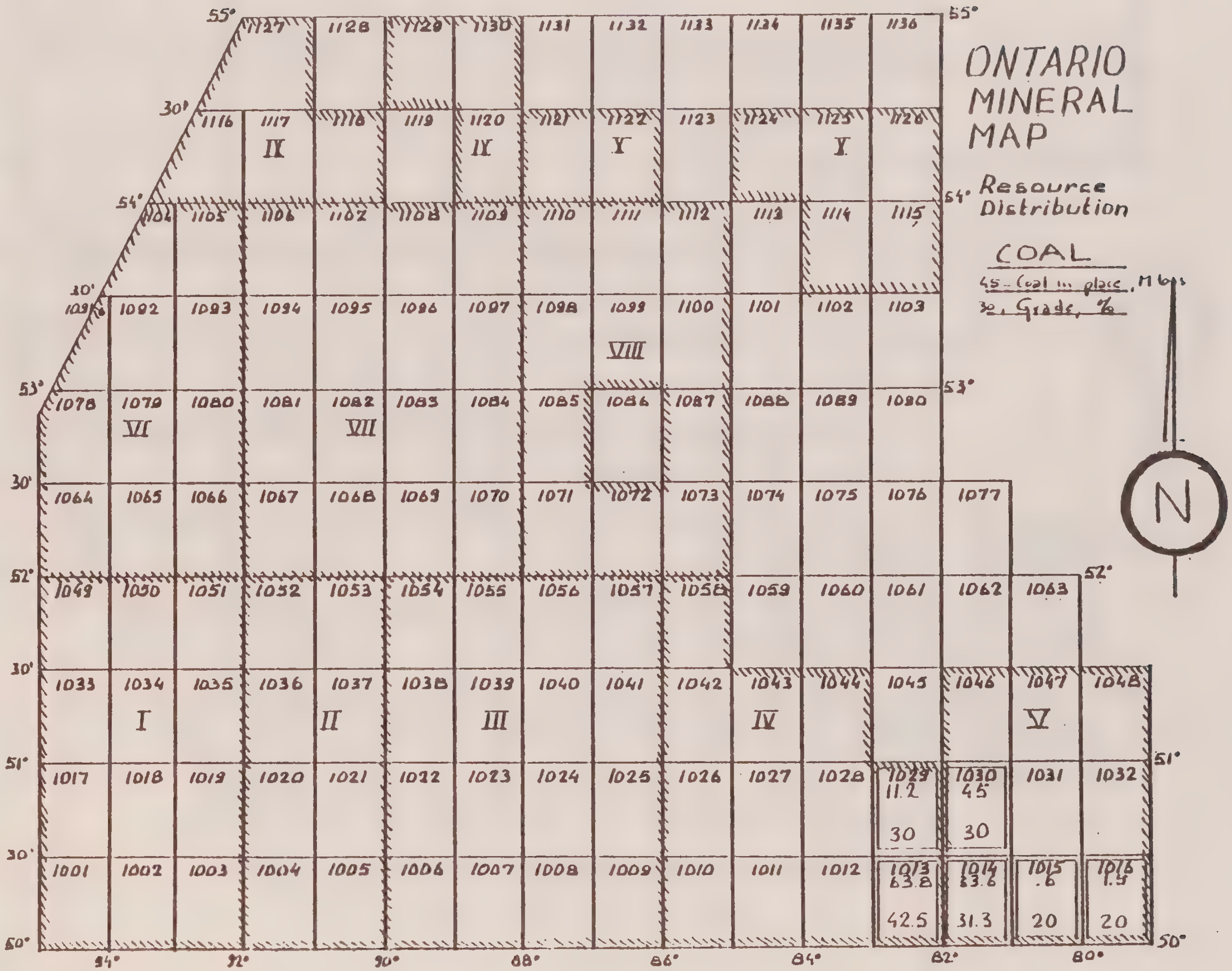


Figure 3 - 13

Coal Deposits Metal in Place and Grade



(Cell 1015) to 63.8 (Cell 1013) million tons of coal in place. The grade of these deposits ranges from 20 percent (Cells 1015, 1016) to 42.5 percent (Cell 1013).

Estimates of the probability that such occurences exist range from 80 percent to 100 percent. Estimates of the probability of development of these deposits vary from 60 percent to 100 percent.

The geologists' assessments insofar as the existence and development of coal deposits are concerned are generally quite optimistic. They assign a probability range of 48 percent to 100 percent that such deposits will be found and developed.

Chromium

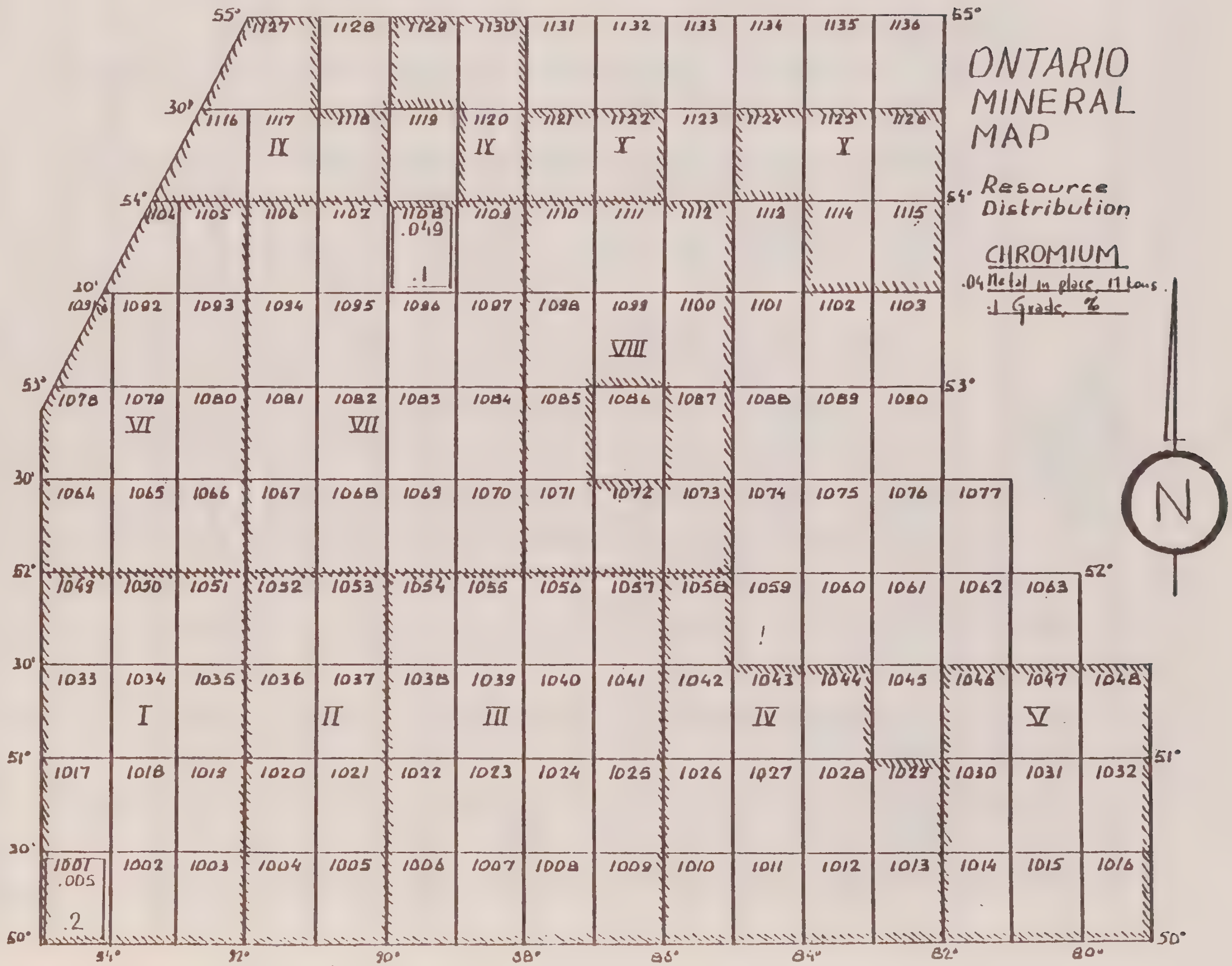
We discovered that there may be about 3 chromium deposits located in 2 cells within the study area. The total metal content of the area is 4.8 million tons of chromium. The total place value of the chromium is $31.11 billion. The deposits vary in size from 0.005 (Cell 1001) to 0.049 (Cell 1108) million tons of chromium in place. The grade of these deposits ranges from 0.1 percent (Cell 1108) to 0.2 percent (Cell 1001).

Estimates of the probability that such deposits exist range from 10 percent to 65 percent. Estimates of the probability of development of these deposits vary from 0 percent to 2 percent for both remote and accessible regions.

The geologists' assessments insofar as the existence and

Figure 3 - 14

Chromium Deposits Metal in Place and Grade



development of chromium deposits are concerned are very pessimistic. They assign a probability range of 0 percent to 1.3 percent for both remote and accessible areas.

Diamond

The geologists suggested that there may be about 6 diamond deposits located in 6 cells within the study area. The total place value of diamond in place is $3.698 billion. The place values of the deposits vary from $273.7 million (Cells 1012, 1028) to $525 million (Cells 1013, 1014, 1029, 1030, 1046, 1047). The grade of the deposits remains constant at $30 per ton.

Estimates of the probability that such deposits exist range from 50 percent to 80 percent. Estimates of the probability of development of these deposits remain fixed at 70 percent.

The geologists' assessments insofar as the existence and development of diamond deposits are concerned reflect relatively minor variation of opinion. They assign a probability range of 35 percent to 56 percent of such phenomena taking place.

Cobalt

The data indicates that there may be only 1 cobalt deposit located in one of the cells within the study area. The total cobalt content of the area is 45 thousand tons. The total place value of the cobalt is $2.212 billion. The grade of the deposit is 1.5 percent.

Figure 3 - 15

Diamond Deposits Mineral in Place and Grade $/ton

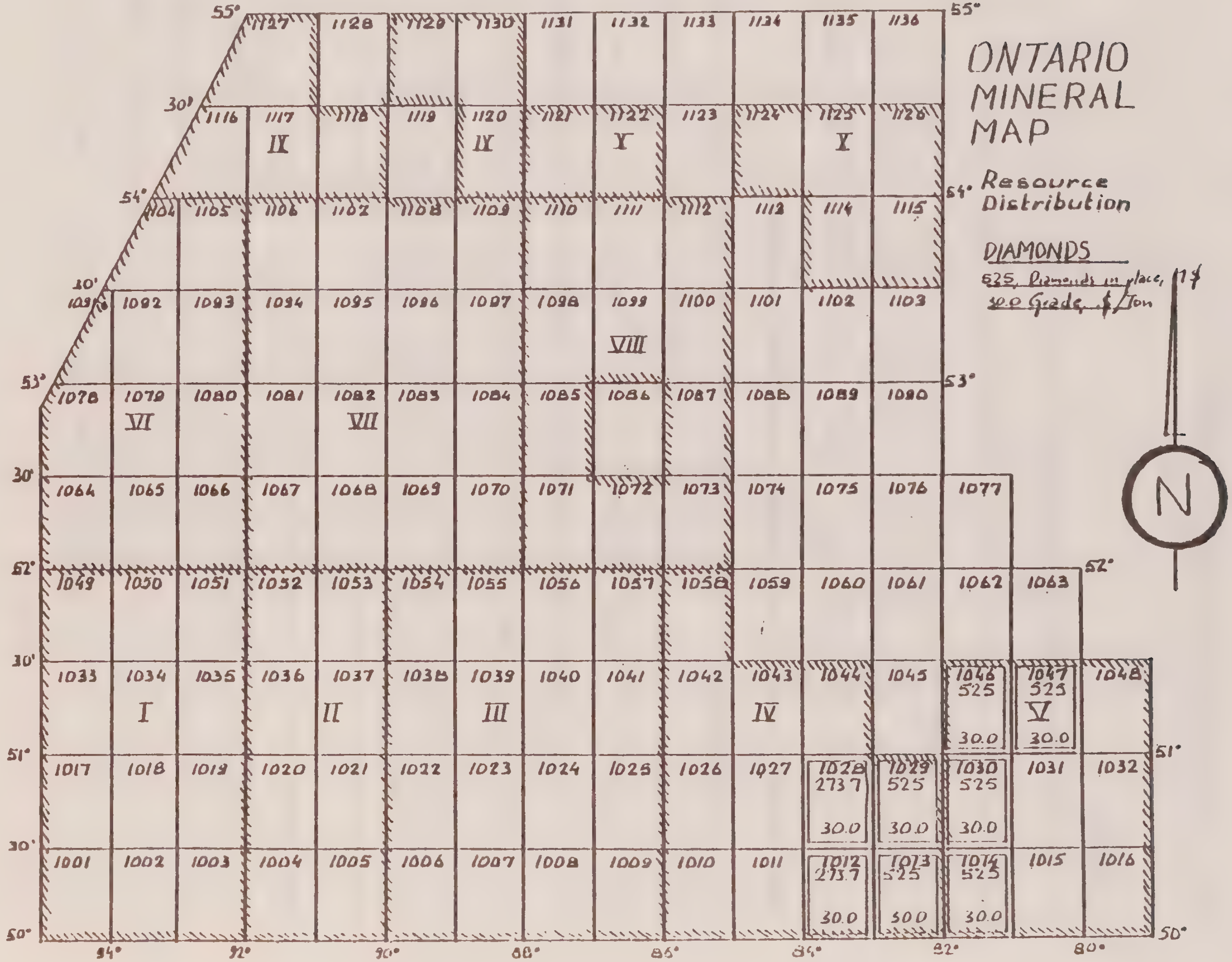
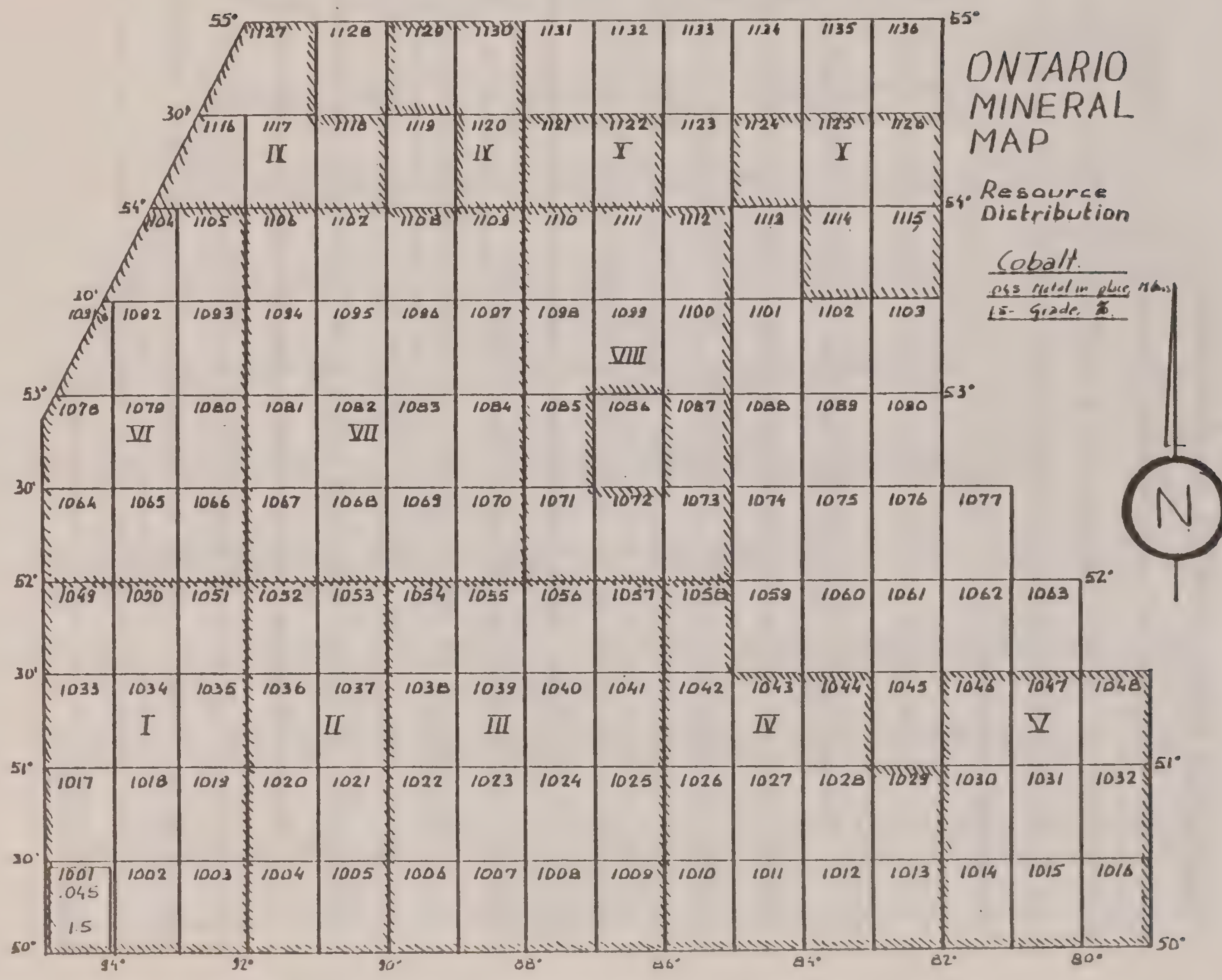


Figure 3 - 16

Cobalt Deposits Metal in Place and Grade



Estimates of the probability that such a deposit exists are expressed as 30 percent. Estimates of the probability of development of this deposit remain fixed at 20%.

The geologists' assessments insofar as the existence and development of cobalt deposits are quite conservative. They assign only a 6 percent probability that such events will occur in the foreseeable future.

Platinum

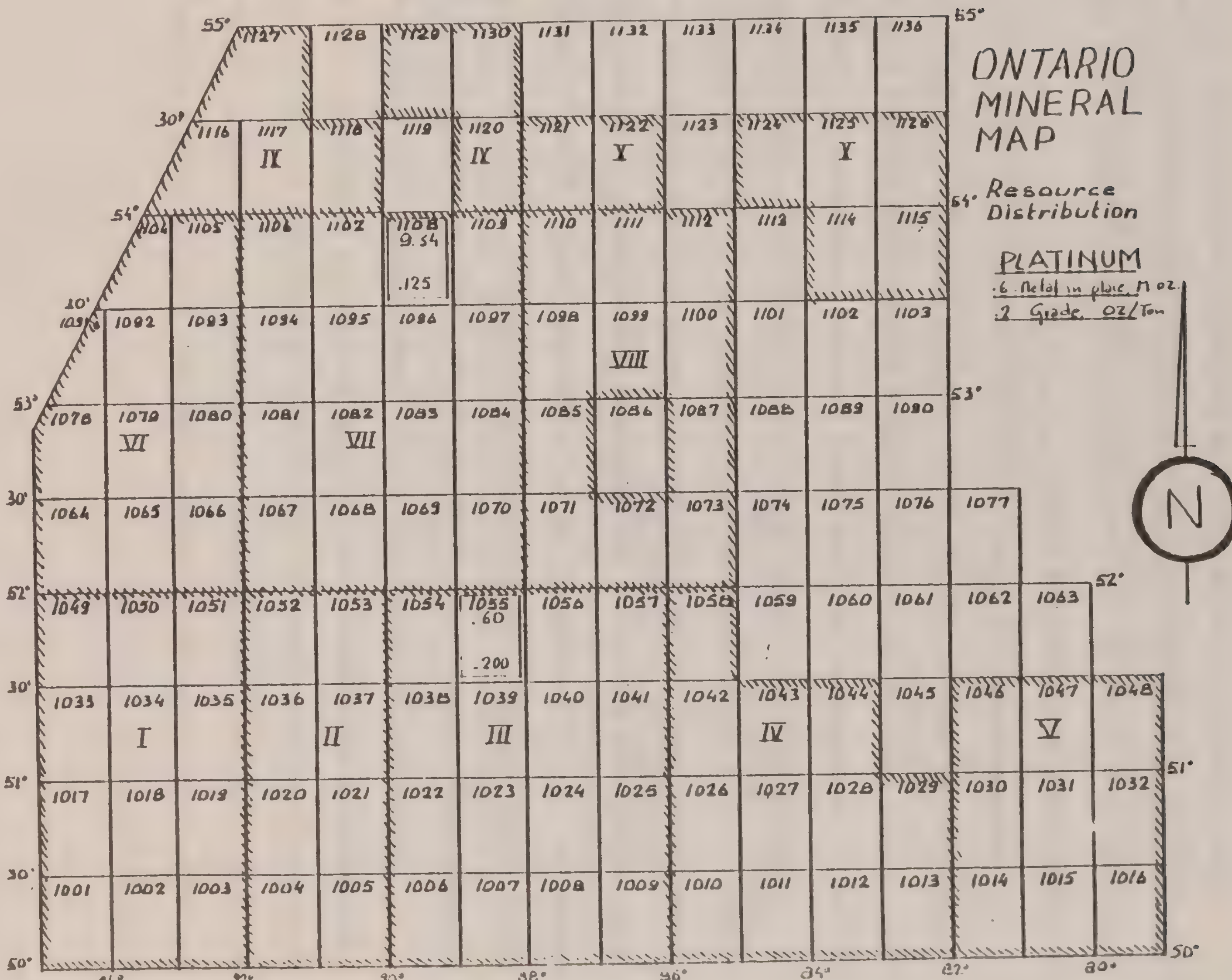
The geological opinions indicate that there may be 2 platinum deposits located in 2 of the cells within the study area. The total platinum content of the area is 9.975 ounces. The total place value of the platinum is $3.514 billion. The deposits vary in size from 0.60 (Cell 1055) to 9.34 (Cell 1108) million ounces of metal in place. The grade of these deposits ranges from 0.125 ounces per ton (Cell 1108) to 0.200 ounces per ton (Cell 1055).

Estimates of the probability that such occurences exist range from 35 percent to 50 percent. Estimates of the probability of development of these deposits vary from 2 percent to 30 percent.

The geologists' assessments insofar as the existence and development of platinum deposits are concerned are obviously quite pessimistic. They assign a probability range of 0.7 percent to 15% to the possibility that such events will occur in the reasonably near future.

Figure 3 - 17

Platinum Deposits Metal in Place and Grade



Conclusion

Our findings insofar as the probable occurence of specific types of mineral deposits are not particularly surprising. The opinions expressed by the geologists tend to conform with the Ontario mineral potential maps.

The pessimism of their forecasts regarding the probability of occurence, and development of mineral deposits is quite apparent. Azis, Barry and Haugh note a similar experience during the course of their research on undiscovered mineral resources in Manitoba.[6]

Despite this gloomy series of predictions, the evidence presented by the geologists does indicate some possibilities insofar as the existence and development of some mineral deposits in the study area. If we use a 60% minimum upper level probability of existence and development as a reference point, then 6 mineral types might well be developed in the future. These are copper-lead-zinc, nickel-copper, gold, silver, iron and coal deposits.

It should be noted that such development will occur only if the deposits are formed and if the return on investment is sufficient to entice mining companies to commit themselves to such large undertakings. In the next chapter, we attempt to identify the sensitive variables which would determine whether or not such ventures would be economically feasible.

NOTES

1. See O. Djamgouz, Climatic and Terrain Conditions of 50th Parallel. A technical report prepared for the Royal Commission on the Northern Environment, September 1981, for more detailed information.

2. The questionnaire and approach used follow closely that of D.P. Harris, A.J. Freyman, and G.S. Barry in "The Methodology Employed to Estimate Potential Mineral Supply of the Canadian Northwest...An Analysis Based Upon Geologic Opinion and Systems Simulation" Mineral Information Bulletin MR 105, Mineral Resources Branch, Department of Energy, Mines and Resources, Ottawa, 1970.

3. See Figure 3 - 1.

4. The specific formulae used in these calculations are provided in O. Djamgouz and A. Farah, The Undiscovered Mineral Potential of Ontario North of 50°N.

5. For more detailed information on the methodology employed see O. Djamgouz and A. Farah, The Undiscovered Mineral Potential of Ontario North of 50°N. A report submitted to the Royal Commission on the Northern Environment, September 1981, pp. 1-18.

6. See A. Azis, G. Barry, and I Haugh, " The Undiscovered Mineral Endowment of the Canadian Shield in Manitoba" , Mineral Bulletin 124, Mineral Resources Branch, Department of Energy, Mines and Resources, Ottawa 1972.

CHAPTER FOUR

THE SENSITIVE FACTORS

Introduction

In previous chapters we examined international and regional factors which could affect the feasibility of mineral development in the study area in the future. In this chapter, a more specialised examination of the effects of a number of variables upon the profitability of new mining ventures in Northern Ontario is presented.

The analytical method used is sensitivity analysis. This procedure allows the researcher to manipulate one factor, such as the grade of the ore deposit, in order to see what alterations occur in our measure of profitability. The internal rate of return - return on investment after taxation - is used to indicate profit margins. Fourteen other variables are manipulated ± 10% in order to determine which factors are " sentitive" . Taxation of mining companies is treated in rather more depth in order to assess the impact of changes in taxation upon mineral development and exploration. The fourteen variables discussed are:

(i) commodity price
(ii) size of ore deposit
(iii) mining cost
(iv) mill recovery
(v) mining recovery
(vi) mill cost
(vii) dilution
(viii) royalty costs
(ix) exploration costs
(x) development cost
(xi) capital costs
(xii) grade of ore deposit
(xiii) environmental costs
(xiv) transportation costs

In addition, the analysis is conducted in such a manner as to provide some indication of the effects of mining methods and production rates on profitability.[1]

The Sensitive Factors

Table 4-1 provides a summary of the important variables in terms of their effect on the profitability of mineral development of certain types of ore deposits. The table indicates that for some types of mineral deposits, such as copper, in certain parts of the study area, a large number of factors are sensitive. For other mineral deposits, such as platinum, only a few of the factors analysed are sensitive.

It is important to note that taxation does not appear in Table 4-1. This occurs because of the particular concern with taxation and a rather different treatment of this topic. As we shall see in the following pages, taxation is an important factor, and, in our view, it is a sensitive variable for all of the types of mineral deposits examined in this study.

The table also demonstrates that six factors - mining costs, milling costs, environmental costs, royalties, transportation costs and exploration costs - were not sensitive. In part, this may be due to the fact that the values for those variables have been adjusted by only ± 10%. In cases of marginally profitable mineral deposits, " all cost changes have substantial impact on profitability."[2]

TABLE 4-1

SENSITIVE FACTORS BY MINERAL DEPOSIT TYPE

MINERAL	SENSITIVE TO
Copper	Grade, Mine Recovery, Price, Size of Deposit, Mining Method, Production Rate, Mill Recovery, Capital Cost
Copper-Zinc	Grade, Mine Recovery, Price, Size of Deposit, Mining Method, Production Rate, Mill Recovery, Capital Cost
Copper-Lead-Zinc	Grade, Price, Size of Deposit, Mining Method, Production Rate, Mill Recovery, Capital Cost
Lead-Zinc	Grade, Price, Size of Deposit, Mining Method, Production Rate, Mill Recovery, Capital Cost
Nickel-Copper	Grade, Mine Recovery, Price, Mining Method, Development Costs, Dilution, Production Rate, Mill Recovery, Capital Cost
Molybdenum	Grade, Mine Recovery, Price, Size of Deposit, Mining Method, Development Cost, Dilution, Production Rate, Mill Recovery, Capital Costs
Uranium	Grade, Mine Recover, Price, Mining Method, Production Rate, Mill Recovery, Capital Cost
Gold	Grade, Mine Recovery, Price, Mining Method, Production Rate, Mill Recovery, Capital Cost
Silver	Grade, Mine Recovery, Price, Mineral Method, Production Rate, Mill Recovery, Capital Cost
Lithium-Columbium	Grade, Mine Recovery, Price, Size of Deposit, Mining Method, Production Rate, Mill Recovery, Capital Cost

MINERAL	SENSITIVE TO
Chromium	Grade, Mine Recovery, Price, Size of Deposit, Mining Method, Development Cost, Production Rate, Mill Recovery, Capital Cost
Cobalt	Grade, Mine Recovery, Price, Size of Deposit, Mining Method, Development Costs, Production Rate, Mill Recovery, Capital Cost
Platinum	Price, Mining Method

One other important consideration which must be made in interpreting the table is the effect of mining methods on potentially sensitive factors. The profitability of underground mining ventures is more affected by changes in development costs than by changes in capital costs. For open pit mining, the analysis indicates exactly the reverse - capital costs are sensitive factors; whereas, development costs are not.

The Effects of Sensitive Factors on Profitability

Table 4-1 indicates that 10 of the factors analysed are sensitive for one or more of the mineral deposits examined in this study. Taxation should also be considered a sensitive variable. In this section of the chapter, we examine each of these sensitive factors and indicate the extent to which they can affect the profitability of future mineral development.

(1) Taxation[3]

In the past ten years, there have been a number of changes in the taxation of mining companies at both the federal and provincial levels of government. In 1971 a series of reforms reduced or eliminated a number of incentives which previously had been available to the mining industries. These changes, when combined with a depressed metals market in the mid-1970's, resulted in extremely high marginal rates and a greater tax burden on the mining industry. A special federal-provincial task force, which analysed the situation, reported in 1978. Partly as a result of

this report more favourable tax rules were introduced by both federal and provincial governments in 1978 and 1979.

The federal tax rate on taxable income is set at a base of 46%. A provincial abatement of 10% is applied so that the net federal tax rate is 36%. A number of additional features are included in federal tax provisions which affect the mineral resource sector of the economy. These are:

1. Federal abatement
2. Investment tax credit
3. Capital cost allowance
4. Inventory allowance
5. Resource allowance
6. Earned depletion
7. Canadian development expense
8. Canadian exploration expense
9. Foreign exploration and development expense

In Ontario the basic income tax rate is 13%. In addition, Ontario possesses some tax rules which differ significantly from those of the federal government.

1. All exploration and development costs incurred after April 9, 1974 may be fully claimed as deductible expenses.
2. An automatic depletion allowance of 33 1/3% of net income before depletion is allowed.
3. No earned depletion or resource allowance deductions are allowed.

Generally speaking, Ontario law requires that profits from all Ontario mines operated by the same taxpayer be aggregated for mining tax purposes. A processing allowance ranging from 15% to

a maximum of 65% has been established to encourage increased processing of minerals within the province.

In order to determine the effects of changes in the taxation rules on the profitability of mining operations, we compared the profitability of identical mining operations for the pre-1971 situation with those of the 1975 situation in Ontario. Both internal rate of return (IRR) and the net present value (NPV) were used as indicators of profit. These indicators are related to the revenue to operating cost ratio (θ).

Figure 4-1 demonstrates the effect on the internal rate of return as a function of the revenue to operation cost ratio when the exploration and development costs are negligible relative to the magnitude of annual income. In effect, this shows the impact of the change from an automatic to an earned depletion allowance. The figure demonstrates clearly that profitability is greater for the pre-1971 tax situation than for the post-1971 situation.

Figure 4-2 demonstrates the effect of the tax changes on the internal rate of return in a case where exploration and development costs are 3/8 of the annual revenue. It should be noted that these costs are incurred prior to the mine going into operation. In this situation, the profitability of the mine is more enhanced by the pre-1971 tax structure than by the newer tax rules.

Figure 4-3 provides net present values for both tax structures. Once again, we can see that from the industry's perspective

Figure 4 - 1

INTERNAL RATE OF RETURN VS. REVENUE-OPERATING COST RATIO
Exploration and development cost=0

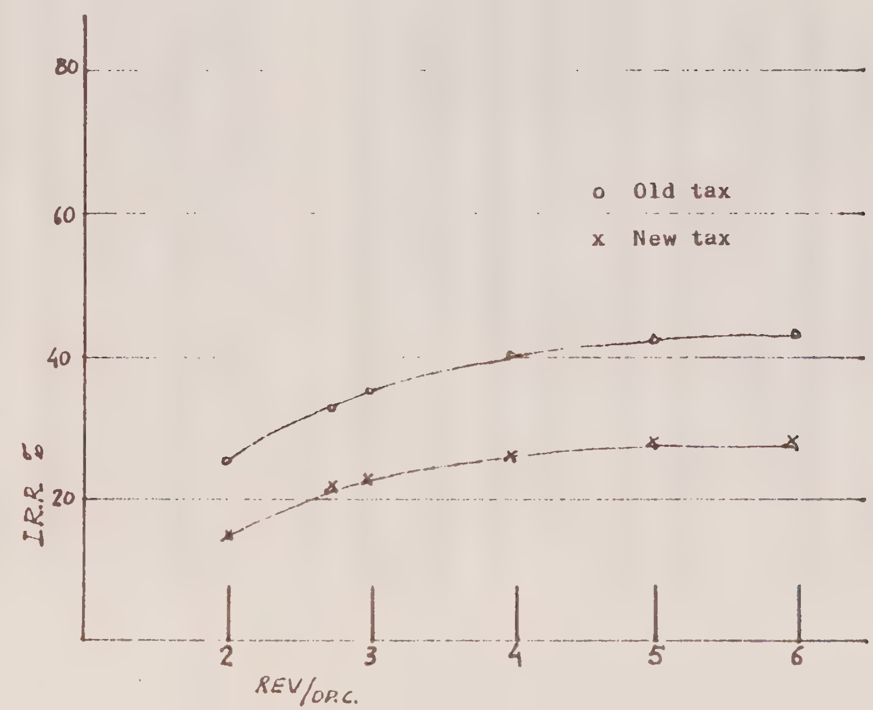


Figure 4 - 2

INTERNAL RATE OF RETURN VS. OPERATING COST RATIO
Exploration and development cost= 0.375 of revenue

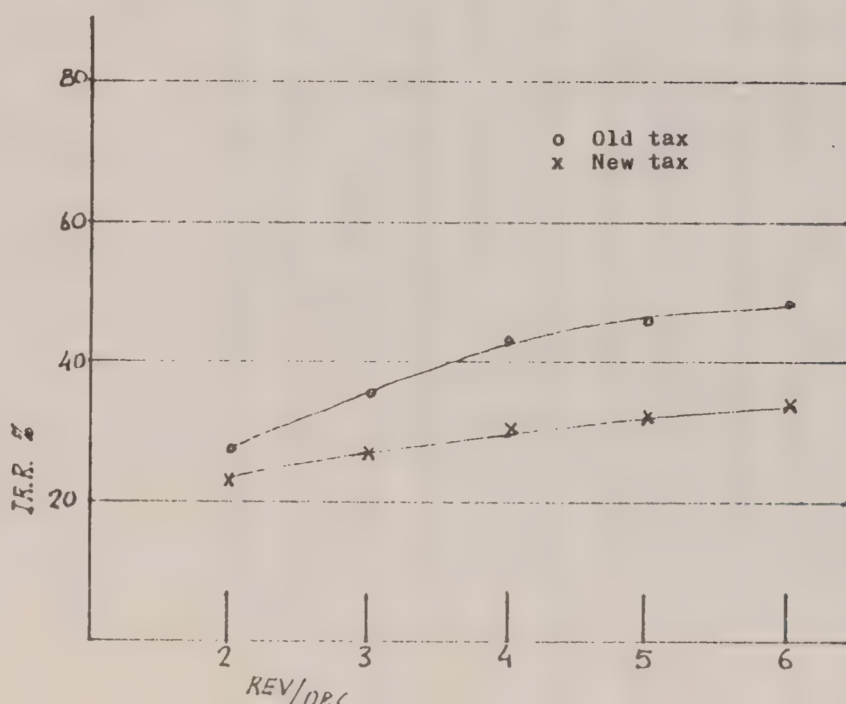
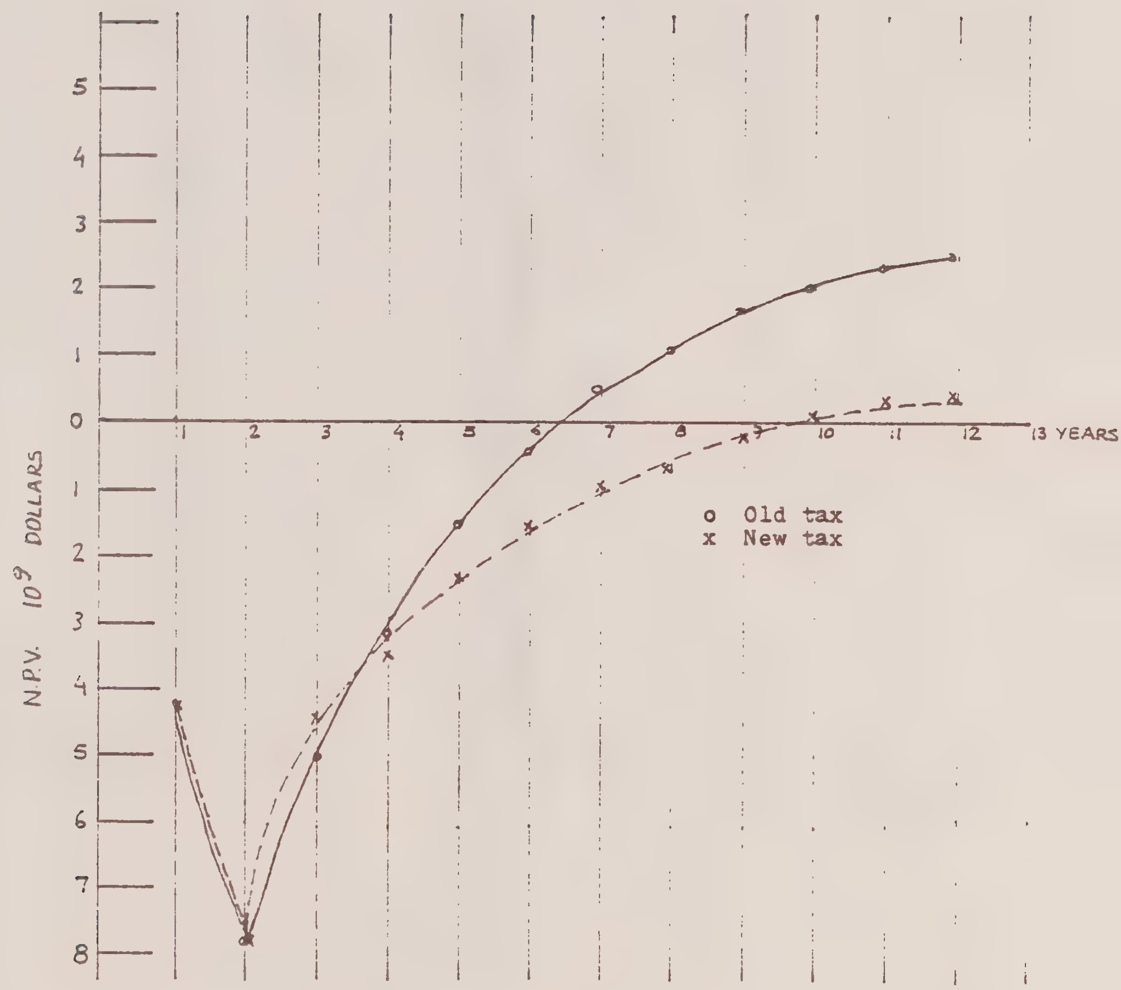


Figure 4 - 3

NPV VS. YEARS
DCF rate =25% and REV./OPC.=2.67



the old structure is preferable to the newer one.

Clearly, changes in the tax structure have had a marked effect on the profitability of mining companies in Ontario. These changes also have affected negatively mineral exploration within the province.

Figure 4-4 demonstrates this clearly. After the tax changes, exploration expenditures drop sharply during the 1970-74 period and improve only modestly in 1975. Other indications of exploration activity such as the amount of drilling done and the number of claims staked also fall in the 1971-74 period.

Taxation structures appear to affect at least two vital aspects of the mineral industry. They may encourage or discourage mineral exploration. They may enhance or reduce the potential profitability of mineral development operations. Without sufficient investment in exploration, we shall not discover new ore bodies. Unless new ore bodies are discovered, little mineral development can occur. Even if new mineral deposits are located, they may not be developed because the level of taxation makes them unprofitable ventures.

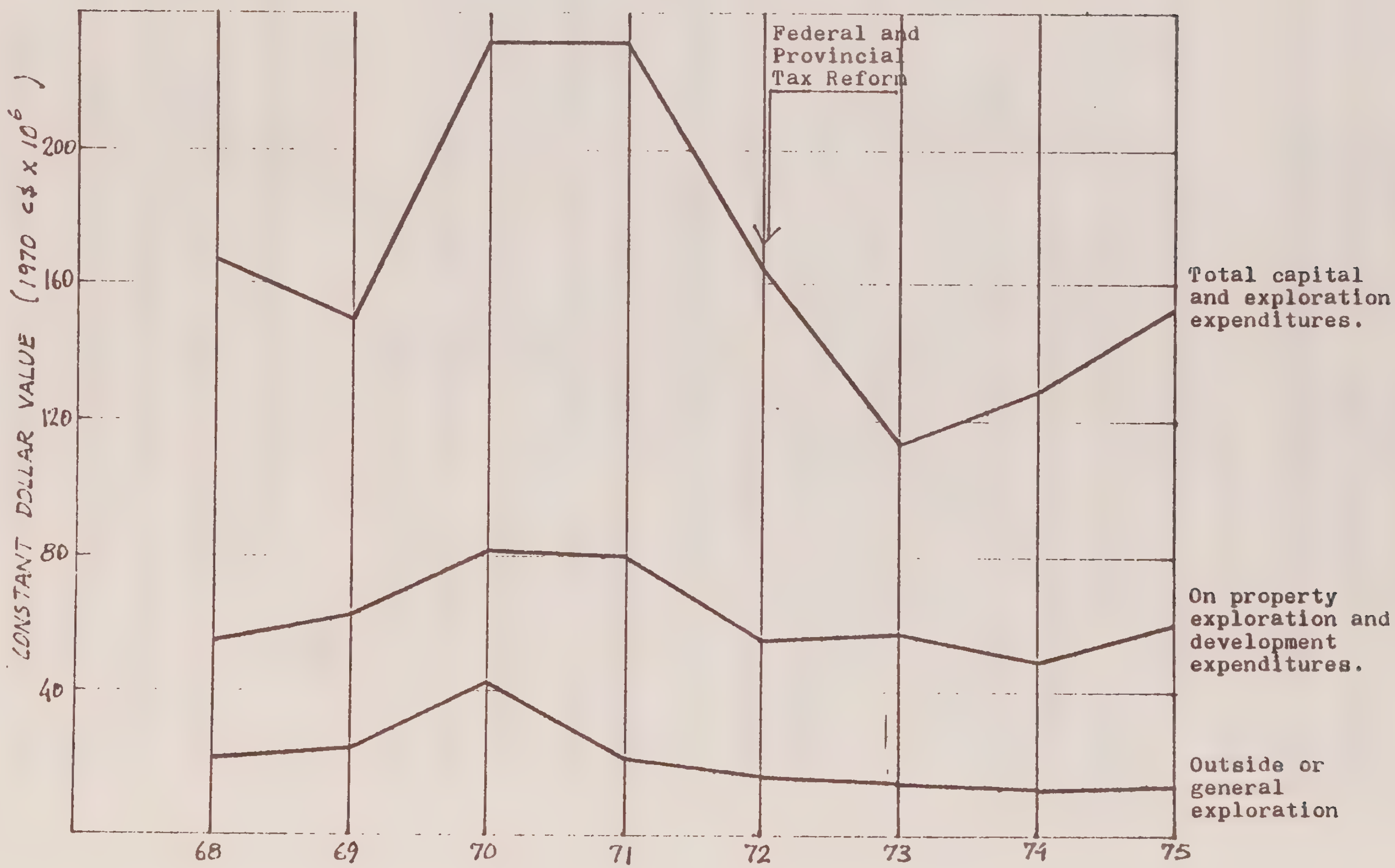
(2) Grade[4]

The sensitivity analysis indicated that the grade of the mineral deposit was frequently a sensitive factor. The grade of an ore deposit has been defined in two basic ways. Normally, it is expressed in percentage terms. (10% of the rock in the deposit is iron ore, for example). In some cases it was expressed more

Figure 4 - 4

IMPACT OF TAX CHANGES ON EXPLORATION IN ONTARIO FOR THE PERIOD 1968-75

Data from J.H. DeYoung.



precisely. For example, we presented the grade in terms of the number of ounces of gold per ton of ore.

The effect of the grade of a mineral deposit on potential profitability of a mining venture varied considerably. In the case of copper-zinc deposits, a 20% fluctuation in grade, at optimum production/day, resulted in only a 4% increase in the IRR in one part of the study area. In the case of cobalt, the increase in the IRR was approximately 150 percentage points.

(3) Mine Recovery

In all mining operations, some of the minerals are lost as a result of the mining process. The amount lost varies according to particular mining methods used. For the purposes of this study the following recovery factors are applied:

Method	Recovery Factor
Open Pit	0.95
Cut and Fill	0.92
Blast Hole	0.84
Shrinkage	0.89
Room and Pillar	0.89

Mine recovery was a sensitive factor for eleven of the mineral deposit types examined by this study. Its effect on the internal rate of return of the various mineral deposits also varied considerably. In the case of silver, a 20% increase in mine recovery, at optimum daily production rates, produced an increase of only 5 percentage points for one deposit area. One cobalt deposit area, however, indicated that a 20% increase in

mine recovery would result in an improvement of 100 percentage points in the internal rate of return.

(4) Price

The prices used in the sensitivity analysis are 1979 market prices which have been presented in a previous chapter. Price was a sensitive factor for 14 of the different types of mineral deposits studied. Its effect on the internal rates of return of these deposits was extremely varied. In the case of platinum a 20% increase in price, at optimum production/day produced an increase of only 3 percentage points in the internal rate of return for one deposit area. One cobalt deposit area suggested an improvement of 180 percentage points in its internal rate of return as a result of a 20% increase in the price of cobalt.

(5) Size of Deposit

The size of mineral deposits was a sensitive factor for seven of the mineral occurrences found in the study area. Deposit size was defined in terms of the total metal content of the deposit. Fluctuations in deposit size tended to produce less variation in profitability than was the case for the factors considered above. In the case of molybdenum, a 20% increase in the size of one deposit produced an increase of only 6 percentage points in the internal rate of return. A 20% increase in the size of one lithium-columbium deposit produced a corresponding increase of 20 percentage points in its internal rate of return.

(6) Mining Method

This factor appeared to be sensitive for 13 of the mineral

deposit types investigated. Basically, we compared the internal rates of return for open-pit mining with cut and fill underground mining methods to determine the sensitivity of this factor. In at least three cases, copper, silver, and iron, the analysis indicated that only if open pit mining were used might these deposits be profitable. Even where both methods were apparently acceptable, dramatic differences existed. In the case of platinum and chromium deposits, at optimum production rates/day, the internal rates of return for open pit mining were 12 percentage points greater than was the case if cut and fill methods were used. In the case of cobalt, the difference was 250 percentage points in the internal rates of return. Open pit mining appeared to be much more profitable than underground mining in all thirteen cases.

(7) <u>Development Costs</u>

This factor was sensitive only for four types of mineral deposits - nickel-copper, molybdenum, chromium and cobalt. Development costs were defined in terms of daily production rates using formulae developed by I.A. O'Hara.[5] Changes in development costs produced quite different results in terms of profitability for these mineral deposits. In the case of nickel-copper, a 20% increase in development costs resulted in a decrease of 6 percentage points in the internal rate of return. For cobalt, at the optimal daily production rate, an increase of 20% in development costs produced a decline of 70 percentage points in the internal rate of return for the deposit.

(8) Mill Recovery

In the case of mill recovery a similar procedure to that used for mine recovery was applied. The major difference was that in the case of mill recovery, a factor was assigned on the basis of the type of mineral being processed.

The mill recovery factors are:

Mineral	Recovery Factor
Copper	0.85
Zinc	0.90
Lead	0.55
Nickel	0.90
Uranium	0.80
Iron	0.87
Lithium-Columbium	0.90
Chromium	0.65
Cobalt	0.88
Platinum	0.77
Gold	0.70
Silver	0.82

Changes in mill recovery produced quite different effects on the profitability of various minerals. A 20% increase in the mill recovery factor for a copper-zinc deposit produced only an increase of 5 percentage points in the internal rate of return. The same increase in mill recovery, when applied to a cobalt deposit, resulted in the internal rate of return increasing by 150 percentage points.

(9) Capital Cost

I.A. O'Hara's formulae provided a means to calculate capital

costs.[6] The basic formulae are:

Open Pit	$\$400{,}000 \cdot T^{0.6}$
Underground	$\$800{,}000 \cdot T^{0.6}$

T = tons of ore mined daily.

Capital cost was a widely sensitive factor. It affected 12 of the mineral deposit types examined. It followed the general pattern in that its effect on profitability varied quite dramatically. A 20% increase in capital costs produced an increase of 7 percentage points in the internal rates of return for nickel-copper and molybdenum deposits in one part of the study area. The same increase in capital cost for a cobalt deposit resulted in the profitability indicator increasing by 150 percentage points.

(10) Dilution

The sensitivity analysis indicated that dilution was only rarely a sensitive factor. Dilution has been defined in terms of the amount of waste rock included with the ore during the mining process. We found that the extent of dilution of ore varied according to the type of mining method employed. The dilution factors were expressed quantitatively as follows:

Mining Method	Dilution Factor
Open Pit	0.16
Cut and Fill	0.08
Blast Hole	0.16
Shrinkage	0.12
Room and Pillar	0.11

The effect of the dilution factor on potential profitability

of mineral development varied considerably. In the case of a nickel-copper deposit, a 20% fluctuation in the dilution factor, at optimum production per day, resulted in only a 4 percentage point alteration in the internal rate of return. For a molybdenum deposit the change in dilution produced a 30 percentage point fluctuation in the internal rate of return.

(11) Production Rate

Our analysis pointed out that production rates were often sensitive. We defined production in terms of the daily tonnage of ore mined. More precisely, we examined the effect on profitability of mining at production rates of 2,000, 4,000 and 8,000 tons per day.

The effect of changing production rates on mine profitability varies dramatically. In the case of an iron deposit an increase in production of 6,000 tons per day resulted in only a 4 percentage point increase in the internal rate of return. In the case of a cobalt deposit the internal rate of return fluctuated by 100 percentage points when changes in production levels were introduced with the analysis.

Conclusion

For most of the mineral deposit types examined in this study, profitability is most sensitive to changes in price, grade, size of the ore deposit, mining method, capital cost, and mine and mill recovery. The somewhat surprising discovery of this

analysis is that mining and milling costs, environmental costs, transportation costs, and exploration costs have only very minimal effects on the variability of profit.

In the next chapter, we shall investigate more thoroughly the potential return on investment which could be gained by mining the potential ore bodies discussed in Chapter III.

NOTES

1. For more detail, see O. Djamgouz and A. Farah, The Undiscovered Mineral Potential of Ontario North of 50°N (A Report submitted to the Royal Commission on the Northern Environment, September 1981), pp. 39-66, 85-96.

2. O. Djamgouz and A. Farah, The Undiscovered Mineral Potential of Ontario North of 50°N, p. 95.

3. See O. Djamgouz and A. Farah, The Undiscovered Mineral Potential of Ontario North of 50°N, pp. 39-59, for more information.

4. The information presented here is gleaned from O. Djamgouz and A. Farah, The Undiscovered Mineral Potention of Ontario North of 50°N, pp. 85-96 and Figures 161-230.

5. I.A. O'Hara, " Quick Guides to the Evaluation of Orebodies" , CIM Bulletin, May 1981, Vol. 74, No. 829, pp. 115-125.

6. I.A. O'Hara, " Quick Guides to the Evaluation of Orebodies" , CIM Bulletin, May 1981, Vol. 74, No. 829.

CHAPTER FIVE

THE PROFITABILITY OF MINERAL DEVELOPMENT

Introduction

In this section of our Report we concentrate on the profitability of developing the mineral deposits which were suggested by our geological investigation.[1] Once again, the internal rate of return is our indicator of profitability. For purposes of this analysis, we use the average 1979 commodity price in our calculations.

It should be pointed out that we discuss only those mineral deposits for which the internal rate of return is in excess of fifteen percent. This choice is a compromise. Few, if any, existing mining companies are achieving such profit margins. At the same time, the executives of these companies indicate to us that they tend to use a twenty percent base from which to seriously consider potential new mineral development projects. Given the fact that interest rates have fluctuated considerably during the past several months, a more precise required return on investment measure is extremely difficult to affix to such an analysis.

By examining each of the minerals deposits for each of the minerals discussed in this Report, we may be able to

obtain a more precise indicator of the potential for mineral development in the study area. We begin by examining the profitability of developing copper deposits.

<u>Copper</u>

Our geological investigation suggested that there may be 24 potential copper deposits in the study area. These deposits have an average grade of 2.4 percent copper. They are located mostly in the Western and North-Western parts of the study area.

Unfortunately, the internal rates of return, using 1979 copper prices, do not indicate a sufficient return on investment to suggest that mineral development might occur. Indeed, none of the 24 deposits, when analysed, produced an internal rate of return of 15 percent or more.

<u>Copper-Zinc</u>

The geological study indicated that there might be as many as 42 copper-zinc deposits scattered primarily throughout the Southern and North-Western parts of the study area. The average grade per deposit was approximately 3.8 percent.

Only one deposit met our 15 percent internal rate of return criterion. This deposit fell within one area from 51 to 51.30°N by 93 to 94°W. At a production rate of 16,000 tons per day, the internal rate of return was determined to

be 15.09 percent. At best, this deposit, at 1979 prices, was extremely marginal in terms of its potential profitability if developed.

Copper-Lead-Zinc

The situation insofar as copper-lead-zinc deposits were concerned was somewhat more positive. Our geological investigation suggested that there might be as many as 102 deposits scattered throughout the Southern and North-Western sections of the study area. The average grade of these deposits was calculated as 8.2 percent.

Six of the deposits produced internal rate of return figures in excess of 15 percent. The first of these fell within an area from 54.30 to 55°N by 91 to 92°W. The internal rates of return varied from 15.9 percent at a production rate of 8,000 tons per day to 22 percent at a production rate of 2,000 tons per day. The second deposit was found within an area extending from 54 to 54.30°N by 90 to 91°W. The internal rates of return varied from 18.1 percent at 4,000 tons per day to 22 percent at 2,000 tons per day. The third deposit was located in an area extending from 51.30 to 52°N by 90 to 91°W. The internal rates of return varied from 15.8 percent at 8,000 tons per day to 22.4 percent at 2,000 tons per day. The fourth deposit occurred within an area ranging from

51 to 51.30°N by 93 to 94°W. Its internal rates of return ranged from 15.9 percent at 4,000 tons per day to 23.5 percent at 8,000 tons per day. The fifth deposit was located in an area extending from 51 to 51.30°N by 86 to 87°W. Its internal rates of return varied from 18.4 percent at a production rate of 4,000 tons per day to 19.6 percent at 8,000 tons per day. The sixth deposit was determined to exist within an area from 50.30 to 51°N by 80 to 81°W. Its internal rates of return ranged from 15.1 percent at 2,000 tons per day to 17.2 percent at 4,000 tons per day.

At best, the internal rate of return was 23.5 percent for deposit four. Given existing interest rates, we would categorise this deposit as marginal. At 1979 prices there did not seem to be sufficiently large profit margins to encourage development of copper-lead-zinc deposits.

Lead-Zinc

The geological study suggested that there would be about 38 lead-zinc deposits concentrated primarily in the centre of the Southern half of the study area. The average grade of these deposits was calculated to be 8.6 percent.

Thirteen of these deposits met our criterion of an internal rate of return of at least 15 percent. The relevant data was as follows:

TABLE 5 - 1

IRR For Lead Zinc Deposits

Deposit Number	Location	IRR	Production Rate
1	51.30 - 52°N 88 - 89°W	20.0%	4,000 T/D
		25.4%	8,000 T/D
		27.3%	16,000 T/D
2	51.30 - 52°N 87 - 88°W	24.8%	4,000 T/D
		25.4%	8,000 T/D
		26.6%	16,000 T/D
3	51.30 - 52°N 86 - 87°W	24.8%	4,000 T/D
		25.4%	8,000 T/D
		26.6%	16,000 T/D
4	51 - 51.30°N 88 - 89°W	18.7%	4,000 T/D
		25.25%	8,000 T/D
		26.0%	16,000 T/D
5	51 - 51.30°N 87 - 88°W	18.7%	4,000 T/D
		25.2%	8,000 T/D
		26.5%	16,000 T/D
6	51 - 51.30°N 85 - 86°W	19.6%	4,000 T/D
		25.1%	8,000 T/D
		26.5%	16,000 T/D
7	51 - 51.30°N 84 - 85°W	19.4%	4,000 T/D
		22.8%	8,000 T/D
		26.5%	16,000 T/D
8	51 - 51.30°N 83 - 84°W	19.1%	4,000 T/D
		23.0%	8,000 T/D
		26.5%	16,000 T/D

TABLE 5 - 1 (continued)

IRR For Lead Zinc Deposits

Deposit Number	Location	IRR	Production Rate
9	50.30 - 51°N 85 - 86°W	19.0%	4,000 T/D
		25.2%	8,000 T/D
		27.9%	16,000 T/D
10	50.30 - 51°N 84 - 85°W	19.1%	4,000 T/D
		23.0%	8,000 T/D
		26.5%	16,000 T/D
11	50 - 50.30°N 85 - 86°W	18.5%	4,000 T/D
		22.0%	8,000 T/D
		26.0%	16,000 T/D
12	50 - 50.30°N 84 - 85°W	18.6%	4,000 T/D
		22.0%	8,000 T/D
		26.5%	16,000 T/D
13	50 - 50.30°N 83 - 84°W	18.8%	4,000 T/D
		22.4%	8,000 T/D
		26,5%	16,000 T/D

The best internal rate of return appears to be 27.9 percent. This occurs for deposit 9 when the production rate is 16,000 tons per day. This rate of return may be sufficient to stimulate investment in the development of this particular lead-zinc deposit in the study area.

Nickel-Copper

The geological research suggested that there may be as many as 24 nickel-copper deposits concentrated in the Western half of the study region. The average grade of these deposits was calculated to be 1.6 percent.

Using 1979 prices, we calculated internal rates of return for all of these deposits. None of them reached the 15 percent cut-off point. Clearly, this indicated that there was not sufficient return on investment to encourage the development of nickel-copper resources of the study region.

Molybdenum

The geological investigation suggested that there might be 7 molybdenum deposits scattered throughout the South-Eastern and South-Western parts of the study area. We calculated the average grade of these deposits to be 0.45 percent.

The pattern for molybdenum was the same as that for nickel-copper. Internal rates of return did not exceed 15 percent. At 1979 prices, it appeared to be unlikely that any

development of the region's molybdenum deposits would take place.

Uranium

The geological study indicated the probable existence of 24 uranium deposits which were located primarily in the Northern and Western sections of the study area. Our calculations indicated that the average grade of these deposits was 2.2 pounds of yellow cake content per ton.

The analysis of internal rates of return indicated that 14 of these deposits exceeded our criterion. The findings have been summarised in Table 5-2.

These internal rates of return suggest more than adequate return on investment for at least two of the deposits. At production rates of 4,000 or 8,000 tons per day both deposit 11 and deposit 13 would appear to provide sufficient profit to encourage development.[2]

Gold

The geological investigation indicated the existence of 87 gold deposits which were concentrated throughout the Western half of the study area. The average grade of these deposits was 0.22 ounces per ton.

Only one of these deposits provided an internal rate of return in excess of 15 percent. This deposit was located in an area extending from 50 to 50.30°N by 79 to 80°W. The

TABLE 5 - 2

IRR For Uranium Deposits

Deposit Number	Location	IRR	Production Rate
1	54.30 - 55°N 91 - 92°W (approx)	18.2%	8,000 T/D
2	54 - 54.30°N 90 - 91°W	18.2%	8,000 T/D
3	54 - 54.30°N 84 - 85°W	18.2%	4,000 T/D
		22.2%	8,000 T/D
4	54 - 54.30°N 83 - 84°W	18.2%	4,000 T/D
		22.2%	8,000 T/D
5	53.30% - 54°N 83 - 84°W	18.2%	4,000 T/D
		22.2%	8,000 T/D
6	53.30 - 54°N 82 - 83°W	18.2%	4,000 T/D
		22.2%	8,000 T/D
7	53 - 53.30°N 88 - 89°W	18.2%	8,000 T/D
8	52.30 - 53°N 93 - 94°W	15.7%	1,000 T/D
9	52.30 - 53°N 89 - 90°W	18.2%	8,000 T/D
10	52.30 - 53°N 88 - 89°W	18.2%	8,000 T/D
11	51.30 - 52°N 91 - 92°W	16.0%	500 T/D
		18.7%	1,000 T/D
		22.7%	2,000 T/D
		38.8%	4,000 T/D
		65.0%	8,000 T/D
12	50.30 - 51°N 94 - 95°W	16.5%	4,000 T/D
		21.0%	16,000 T/D
13	50 - 50.30°N 89 - 90°W	17.5%	1,000 T/D
		44.5%	4,000 T/D
		51.4%	8,000 T/D
14	50 - 50.30°N 88 - 89°W	15.4%	500 T/D
		21.0%	1,000 T/D
		18.4%	2,000 T/D
		18.6%	4,000 T/D

internal rates of return for this deposit varied from 15.4 percent at a production rate of 16,000 tons per day to 19.9 percent at 2,000 tons per day.

These rates of return are such that, in our opinion, this gold deposit in the region should be classified as marginal in terms of their potential profitability at the present time.

Silver

Our geological research findings indicated that there may be 47 silver deposits, located primarily in the South-Western section of the study area. The average grade of these deposits was 2.2 ounces per ton.

Using 1979 silver prices, we calculated the internal rates of return for these deposits. None of them achieved the 15 percent cut-off point. This result demonstrated clearly the fact that there was not sufficient return on investment to encourage the development of the silver resources of the region.

Iron

The geological investigation revealed that there may be 34 iron deposits which are located primarily in the South-West section of the study area. The grade of these deposits averages 27 percent.

Our analysis of the internal rates of return indicated

that none of these deposits would produce a return of more than 15 percent. It appeared to be highly unlikely that any significant development of the iron resources of the study area would be encouraged by such low profit margins.

Lithium-Columbium

We found that there may be 26 different lithium-columbium deposits in the region North of 50°N. They tended to occur in the Western half of the study area. The average grade of these deposits was 1.6 percent.

For eleven of these mineral deposits, the internal rates of return indicated return on investment in excess of 15 percent. The details were as indicated in Table 5-3.

For 8 of the lithium-columbium deposits the internal rates of return are sufficiently large to encourage their development.

Chromium

The geological evidence indicated that there may be 3 chromium deposits scattered in various sections of the Western half of the study area. The average grade of these deposits was calculated to be 17.5 percent.

Using 1979 prices we calculated the internal rates of return for these deposits. None of them achieved the 15 percent cut-off point. This result illustrated the fact that

TABLE 5 - 3

IRR For Lithium-Columbium Deposits

Deposit Number	Location	IRR	Production Rate
1	54.30 - 55°N 91 - 92 (approx)°W	15.5%	500 T/D
		19.2%	1,000 T/D
		24.0%	2,000 T/D
		38.2%	4,000 T/D
		62.0%	8,000 T/D
		69.0%	16,000 T/D
2	54 - 54.30°N 90 - 91°W	15.3%	500 T/D
		18.2%	1,000 T/D
		22.2%	2,000 T/D
		39.2%	4,000 T/D
		65.2%	8,000 T/D
		68.8%	16,000 T/D
3	53 - 53.30°N 88 - 89°W	15.8%	500 T/D
		18.5%	1,000 T/D
		23.2%	2,000 T/D
		39.5%	4,000 T/D
		65.2%	8,000 T/D
		74.5%	16,000 T/D
4	52.30 - 53°N 89 - 90°W	15.7%	500 T/D
		18.5%	1,000 T/D
		25.2%	2,000 T/D
		47.6%	4,000 T/D
		49.4%	8,000 T/D
5	52.30 - 53°N 88 - 89°W	15.7%	500 T/D
		18.5%	1,000 T/D
		23.0%	2,000 T/D
		39.2%	4,000 T/D
		65.0%	8,000 T/D
		69.0%	16,000 T/D

TABLE 5 - 3 (continued)

IRR For Lithium-Columbium Deposits

Deposit Number	Location	IRR	Production Rate
6	51.30 - 52°N 88 - 89°W	16.1%	500 T/D
		22.1%	1,000 T/D
		29.6%	2,000 T/D
		28.8%	4,000 T/D
7	51.30 - 52°N 80 - 81°W	15.9%	500 T/D
		19.7%	1,000 T/D
		24.0%	2,000 T/D
		27.0%	4,000 T/D
		39.2%	8,000 T/D
8	51.30 - 51°N 92 93°W	16.8%	500 T/D
		19.0%	1,000 T/D
9	50.30 - 51°N 91 - 92°W	15.5%	500 T/D
		20.0%	1,000 T/D
		25.0%	2,000 T/D
10	50 - 50.30°N 88 - 89°W	18.3%	250 T/D
		28.0%	500 T/D
		40.0%	1,000 T/D
11	50 - 50.30°N 81 - 82°W	18.2%	250 T/D
		21.0%	500 T/D
		27.4%	1,000 T/D
		34.6%	2,000 T/D
		61.0%	4,000 T/D
		111.0%	8,000 T/D
		135.0%	16,000 T/D

was not sufficient return on investment to encourage the development of the chromium resources of the region.

Cobalt

The geological evidence suggested that there was one cobalt deposit located in the South-West corner of the study area. The grade of this deposit was 1.5 percent.

The internal rate of return indicates that this is a potentially profitable deposit. At a production rate of 250 tons per day, the internal rate of return is 39.3 percent. At 500 tons per day, the internal rate of return is 44.8 percent. At 1,000 and 2,000 tons per day, the returns on investment are 82 and 150 percent, respectively.

Platinum

The geological investigations suggested that there may be 2 platinum deposits. One is in the North-Western section and one is in the South-Western section of the region. The average grade of these deposits is 0.16 ounces per ton.

The internal rates of return for these deposits do not exceed 15 percent. It appears that, at 1979 prices, the platinum resources of the region are not sufficiently profitable to warrant development.

Conclusion

In this section of our Report, we calculated the internal

rates of return for the mineral deposits suggested by the geological study which was discussed above. By using 1979 prices, we were able to produce a fairly precise measure by which the potential profitability of mineral development could be estimated.

The results of this exercise are mixed. Of the fourteen types of mineral deposits analysed, eight do not seem to be sufficiently profitable to encourage development. The future insofar as the development of the potential copper, nickel-copper, molybdenum, gold, silver, iron, chromium and platinum resources of the region appears to be quite pessimistic at least for the next several years. Three minerals - cobalt, lithium-columbium, and uranium[3] - produce extremely high internal rates of return at 1979 prices. This suggests a more optimistic future for the development of these minerals in the future. Three of the mineral deposit types - copper-zinc, copper-lead-zinc, and lead-zinc - indicate sufficient profitability to suggest that mineral development may take place in the future if prices rise at least moderately.[4]

NOTES

1. See above, Chapter III, pp. 55-88.

2. This must be qualified dramatically because of falling uranium prices. See Chapter VI, p. 129 for more detail.

3. The qualification introduced previously must be repeated to indicate that the IRR for the uranium deposits under current prices will be dramatically lower than they are when 1979 prices are used.

4. See Figures V-1 to Figure V-7 in Appendix A, pp. 147-153.

CHAPTER SIX

CONCLUSION: A NOTE OF OPTIMISM

Our major concern in conducting the research on behalf of the Royal Commission on the Northern Environment has been to determine if mineral development North of 50°N in Ontario is likely to take place. This concern is a logical one. Ontario's economic status within Canada is changing from that of a "have" to a "have not" province. In addition, Ontario's status as a mineral producer, both domestically and internationally, has declined considerably during the past three decades. Significant mining activity in the study region would stimulate not only the local economy, but also that of the province.

In order to come to some conclusion regarding the possibilities for mining in Northern Ontario, we attempt to answer four basic questions:

1. Are there undiscovered mineral deposits in the region North of 50°N?
2. Would the necessary investment be available for the development of such deposits?
3. Would any of these deposits be profitable now if they were developed?
4. Is profitability likely to be enhanced in the future?

In this final chapter, our answers are presented in a brief fashion.

The geological investigation indicated the presence of one or more deposits of some sixteen minerals. These minerals occured in copper, copper-zinc, copper-lead-zinc, lead-zinc, nickel-copper, molybdenum, gold, uranium, silver, iron, coal, lithium-columbium, chromium, diamond, cobalt and platinum deposits. In general, geological opinion was that these deposits were relatively small and of rather low grade.

Such pessimism is not surprising. Conservative estimates of this type seem to be the rule rather than the exception in this type of research. Even though the probability that these mineral deposits do exist may be high, such deposits must be found before they can be developed.

Exploration, then, is a crucial factor in this process. The geologists, whom we interviewed, tend to agree that there are two obstacles to exploration in the region. One of these is the lack of access roads. Such roads would enhance interest in the region and increase the number of discoveries. The second limitation is the relatively small amounts of money which are being spent on exploration in the region.

> Although the average annual exploration budgets ranged from $100,000 to $250,000, the general concensus was that a minimum budget of the order of $5 million will be needed to locate an economical base metal ore-body. For an economic iron ore-body the exploration budget should be in the $7 to $10 million, range.[1]

Although we know of some ore-bodies in the area (iron ore in Lake St. Joseph region, for example), a considerable amount

remains to be done if we are to find economic deposits for future development.

It should also be pointed out that there is likely to be a pattern insofar as the discovery and development of new mineral deposits are concerned. New mineral deposits are most likely to be found in the regions near existing mining camps where access is easier and geological knowledge is greater. This pattern is a long established one in the expansion of mining sites in Ontario. Such an historical pattern helps to explain why the geologists assigned a higher probability of discovery and development to potential deposits in the southern part of the study region than to possible ore-bodies further north.[2]

If an economic mineral deposit is found in the study region, it is likely that the necessary investment can be found. Canada is highly regarded in investment circles. Ontario's climate is one of relative stability and includes a positive attitude towards private investment within the province. Such investment will not take place, however, unless potential investors are confident of a reasonable return on investment. The response to the third question could be developed in a very pessimistic fashion. Geological opinion indicated that only six types of deposits - copper-lead-zinc, nickel-copper, gold, silver, iron, and coal - were likely to be found and developed in the foreseeable future. Our analysis of internal rates of return, using 1979

prices, indicated that, at best, only two - copper-lead-zinc and gold - were sufficiently profitable to attract investment.

Such pessimism is, in our opinion, unwarranted. There are a number of reasons to postulate a more positive future for mineral development in the region.

Our analysis of profitability, using 1979 prices, identified seven types of deposits within the study area for which the internal rate of return was in excess of fifteen percent. These included copper-zinc, copper-lead-zinc, lead-zinc, gold, lithium-columbium, uranium and cobalt. For some of the lead-zinc, lithium-columbium, uranium and cobalt deposits, the internal rates of return were calculated to be greater than twenty-five percent. In the case of uranium, however, this finding was quite misleading. The geologists felt that there would be no significant uranium development in the region in the foreseeable future. Our economic forecasts supported their conclusion. The dramatic fall in uranium prices over the past two years provided further evidence that uranium development on any large scale is highly unlikely for the next several years. For other types of mineral deposits, however, the future may be much more encouraging.

In the case of gold, Dr. Strauss and Dr. Willauer indicated that major opportunities for increased production would probably occur in the future.[3] Our forecasts suggest a dramatic increase in the price of gold during the next

several decades. They also indicate that world production increases of gold will be relatively slight. In view of this, it appears to be quite likely that we should expect to see new gold developments in the study area before the turn of the century.

By extrapolating the price required to produce an internal rate of return of twenty-five percent, we are able to indicate more precisely the period in which such development would become economically attractive to potential investors.[4] If the gold deposits described in Chapter III were found, our analysis indicates that at current prices, applying open pit mining methods, deposits in the south-western, south-central and south-eastern sections of the study region would generate an internal rate of return of 25 percent. If more expensive cut and fill methods were necessary only those deposits in the south-central and south-eastern parts of the study area would generate such a return. By 1989 however, if prices rise as our forecasts indicate, then, the deposits in the south-western sections of the region would also provide a 25% I.R.R. on investment.

For copper-zinc deposits the future also appears to be bright. Although opportunities should develop in the case of these two minerals, Ontario will face considerable international competition. We forecast an increase by a factor of 7.8 for copper and a factor of 5.9 for zinc in world production. Our price forecasts indicate that in 2004 the price

of copper might be 255% of 1979 prices. For zinc, the 2004 price is 370% of the 1979 price. On this basis, we anticipate that in the future investors would find it profitable to provide the capital necessary for the development of some of the copper-zinc resources of the region.

By 1985, we expect that the potential copper-zinc deposits in the south-east and south-west sectors if mined by open pit methods, would generate an internal rate of return of 25%. If cut and fill mining methods were necessary, such a return on investment for copper-zinc production in these two areas would not occur until approximately 1990.

In the case of copper-lead-zinc deposits, a similar scenario emerges. We expect that by 2004, the price of lead will be 279% of its 1979 price. World production will have increased by a factor of about 4.4. Although increased competition for investment in such developments is probable, it is also quite likely that new copper-lead-zinc developments in the study area would be economically feasible. Indeed, at optimum production rates of 8,000 tons per day using open pit mining, virtually all of the deposits discussed in Chapter III would be attractive at the present time. By the late 1980's or early 1990's the same return of investment would be received in cut and fill mining operations.

For lead-zinc deposits in the study area, the future appears to be similar to that outlined immediately above. We would expect future development of these resources to

to take place, but a somewhat late date.

If open pit mining at optimum production rates were used, an internal rate of return of 25 percent for potential deposits in the south-eastern and south-western parts of the study area might be realised by the late 1980's. If cut and fill methods are required, then the forecast prices of the first half of the 1990's would be sufficient to produce the profit margin.

Our projections for copper production and prices have been presented above. In the Report on Copper, Dr. Strauss indicates that there should be real opportunities for the development of copper reserves in the future. We estimate that by the mid 1990's, the deposits in the south-east sector of the region would generate an internal rate of return of 25 percent if they were mined using open pit methods.

In the case of nickel-copper deposits, the projections suggest a more cautious conclusion. Although the long-term future for copper appears to be a favourable one, the situation for nickel is rather more complex. If nickel prices in 2004 are 272% of their 1979 value as we forecast them to be, then some of the deposits are likely to be economically attractive. The problem is that we expect world nickel production to increase by a factor of 10.7 during this period. Clearly the competition among countries for investment is likely to be very strong indeed. From this perspective, the development of nickel-copper resources in the study area depends on the

extent of the potential profitability of such an investment.

Although some of the potential deposits in the south-west and south-central sectors might be profitable at 1979 prices if open pit extraction were feasible, these deposits would not become economically attractive until the end of the 1980's if more expensive cut and fill methods proved to be necessary.

The future for the development of molybdenum resources appears to be excellent. Although we project that world molybdenum production in 2004 will be 1,720% of 1979 production, the price is forecast to increase sixfold during the same period. The difficulty for the study area is not economic; it is geological. It is unlikely that we shall uncover deposits of sufficient size and grade to justify their development.

If the deposits suggested by the geologists did exist and were found, our analysis indicates that they would be economically viable by the mid 1980's.

The situation for silver is rather more optimistic. We expect the price in 2004 to be 684% of its 1979 value. We expect production to increase by a factor of 5.5. Dr. Strauss feels that real opportunities will exist, despite some uncertainties, in the future. By the latter half of the 1980's the possible deposits in the north-western, south-eastern and south-central regions should be profitable if they were mined using open pit methods.

In the case of iron, the future is a less optimistic

one. Although deposits do exist in the region they are of relatively low grade when compared to the iron riches of other parts of the world. In addition, we forecast only a doubling in price of iron by 2004. During the same period we expect that world iron production will increase to 883% of its 1979 level. On this basis, we do not assign a very high probability that the iron resources of the region will undergo major development for the next decade or more. Indeed, our analysis indicates that the potential deposit in the south-central sector would not be economically attractive until after the turn of the century.

Although platinum may well continue to be extracted from other mineral-bearing ores, its future is not likely to stimulate major new development. We forecast a massive increase in world production and only a modest increase in price. On this basis, we do not expect that the platinum resources of the region will be sufficiently profitable to encourage their development in any major way. Our analysis indicates that the only economically viable potential deposit is in the north-central section of the study region. This deposit would not be viable until the early 1990's and even then, it would only generate an attractive return on investment if open pit mining were possible.

In the cases of lithium-columbium, cobalt and chromium, the conclusions are more difficult to reach because our econometric analysis did not include these minerals. It appears that some of the potential deposits would be economically

feasible at 1979 prices. If the prices of these minerals continue to increase, then they should become even more attractive to investors interested in mineral development at some future date.

The best advice and information available to us indicates that there is a future for mineral development in Ontario north of 50°N. A great deal of work remains to be done if these opportunities are to be grasped. Our work on this challenging project leads us to believe that there is a great potential for mineral development in the area during the next two decades.

The results of our analysis warrant some optimism insofar as the future of mineral development in Northern Ontario is concerned. The opportunities indicated in this Report must be interpreted with some caution. The mineral deposits which we have been told might exist have not yet been found. If world economic growth is less than the advice received from the United Nations, the prices will not rise as quickly as we have indicated in the text.

NOTES

1. O. Djamgouz and A. Farah, <u>The Undiscovered Mineral Potential</u>..., p. 18.

2. See O. Djamgouz and A. Farah, <u>The Undiscovered Mineral Potential</u>..., pp. 15-18, 37-39.

3. H. Strauss and E. Willauer, <u>Report on Gold</u>.

4. See O. Djamgouz, <u>Sensitivity of I.R.R. to Price Changes and Determination of Economic Threshold and Desired I.R.R.</u> A Report prepared for the Royal Commission on the Northern Environment, August 1982.

APPENDIX A

TABLES AND FIGURES

Table I-1

Percentage World Mineral Production
- Best Year[1], 1977[2] and 1979 -
Canada

Mineral	Best Year	1977	1979
Lead	10.93 (1972)	8.69	8.77
Copper	11.02 (1967)	9.76	8.24
Gold[3]	18.58 (1951)	5.36	5.16
Molybdenum	18.3 (1970)	17.3	10.9
Uranium[3]	37.0 (1958)	20.1	18.1
Silver	17.5 (1967)	13.0	11.3
Nickel	75.2 (1950)	29.4	19.5
Zinc	23.1 (1967)	18.3	18.3
Platinum Group Minerals	39.3 (1962)	7.3	2.8
Iron	7.4 (1968)	6.6	7.2

Source: United Nations, <u>Statistical Yearbooks</u>. (New York: U/N/, various years)

1 Best year means largest percentage of world production during the 1950-1979 period.

2 1977 is chosen because of the effects of the exceptionally long strike at INCO's Ontario operation in 1978-79.

3 Share (percentage) non-communist world production only.

Table I-II

Percentage World & Canadian Mineral Production
- Best Year[1], 1977[2] and 1979 -
Ontario

Mineral	% World Production			% Canadian Production		
	Best Year	1977	1979	Best Year	1977	1979
Lead	0.31 (1972)	0.25	0.24	3.11 (1974)	2.90	2.73
Copper	4.96 (1967)	3.60	2.37	51.56 (1953)	36.86	28.72
Gold[3]	10.42 (1951)	2.31	2.32	59.85 (1959)	42.69	39.15
Uranium[3]	29.4 (1959)	12.6	11.5	86.90 (1975)	62.69	63.53
Iron Ore	1.7 (1968)	1.3	0.98	67.05 (1950)	19.25	13.57
Nickel	75.2 (1950)	22.8	14.0	100.00 (1950)	77.41	72.11
Platinum Group Mineral	39.3 (1962)	7.3	2.8	100.00	100.00	100.00
Silver	7.8 (1968)	5.2	4.2	51.14 (1969)	39.91	36.95
Zinc	7.8 (1974)	5.1	4.4	38.64 (1974)	27.60	24.05
Molybdenum	0	0	0	0	0	0

Sources: United Nations, Statistical Yearbooks (New York: United Nations, various years)
ABMS, Non-Ferrous Metal Data (New York: ABMS, various years)
W. Strauss, Technical Information Paper No. 2

1 Best Year means the largest percentage of production during the 1950-1979 period

2 1977 is chosen because of the effects of the exceptionally long strike at INCO's Ontario operations in 1978-79.

3 Share (percentage) of non-communist world production only.

TABLE II-1

World Mineral Production
1950 - 1979

Mineral	1950	1955	1960	1965	1970	1975	1979
Gold[1]	752	836	1,044	1,278	1,291	987	954
Nickel[2]	149.3	250	337	458	657.3	757	676.6
Silver[1]	5,500	6,100	6,300	6,800	9,620	9,330	10,519
Lead[2]	1,540	1,950	2,430	2,750	3,420	3,410	3,599
Zinc[2]	2,274	2,915	3,380	4,360	5,530	5,470	6,264
Molybdenum[1]	14,230	30,100	40,410	52,390	83,500	82,610	103,066
Platinum[3]	419.6	960	1,316.1	3,563.1	4,328.9	5,713.7	6,659.5
Copper[2]	2,470	3,065	4,120	5,090	6,500	7,400	7,910
Iron[4]	116.8	174.5	256.6	326.4	421.3	522.5	506.6
Uranium[1]	-	-	37,305	18,653	18,201	19,080	44,977

[1] metric tons
[2] 000 metric tons
[3] 000 troy ounces
[4] 000,000 metric tons

Source: H. Strauss and E. Willauer
<u>Mineral Reports</u>
(Submitted to the Royal Commission
on the Northern Environment May-Sept., 1981).

TABLE II-2

World Mineral Production Forecasts

1980 - 2004

Mineral	1980	1985	1990	1995	2000	2004
Gold[1]	946.31	903.88	797.79	656.18	508.59	400.04
Nickel[2]	733.04	905.95	1,078.86	1,251.78	1,424.69	1,597.60
Silver[1]	11,554.7	14,172.8	17,034.4	20,902.8	25,735.6	30,454.2
Lead[2]	3,833.81	4,366.29	4.091.28	5,518.71	6,208.33	6,817.91
Zinc[2]	6,457.2	7,867.4	9,277.6	10,687.8	12,097.9	13,508.1
Molybdenum[1]	106,725	126,008	148,407	175,849	210,262	244,198
Platinum[3]	7,921,3	15,189.4	22,457.4	29,725.5	36,993.6	44,261.6
Copper[2]	8,261	10,478	12,694	14,911	17,127	19,344
Iron[4]	538.7	637.4	736.1	834.8	933.5	1,032.2
Uranium[1]	56,547	54,272	44,193	42,111	43,996	47,083

1 metric tons
2 000 metric tons
3 000 ounces
4 000,000 metric tons

Source: H. Strauss and E. Willauer
<u>Mineral Reports</u>
(Submitted to the Royal Commission
on the Northern Environment May-Sept., 1981)

TABLE II-3

World Mineral Consumption

1950 - 1979

Mineral	1950	1955	1960	1965	1970	1975	1979
Nickel[1]	158.2	206.9	292.7	425.4	572.0	577.4	798.2
Silver[2]	201.5	245.4	328.5	717.7	365.8	414.8	432.8
Lead[1]	1,340.4	2,106.3	2,271.7	2,794.5	3,542.1	3,634.3	3,925.9
Zinc[1]	1,985.7	2,692.4	3,077.3	4,016.6	4,639.1	5,035.2	6,178.7
Copper[1]	2,642.8	3,513.2	4,244.1	5,633.5	6,638.2	7,430.0	9,792.8
Iron[3]	188.6	264.3	346.6	458.9	593.9	643.9	745.3

[1] 000 metric tons
[2] million troy ounces
[3] 000,000 tons
crude steel production

Source: H. Strauss and E. Willauer
Reports on Minerals
(Submitted to the Royal Commission
on the Northern Environment May-Sept., 1981).

TABLE II-4

World Mineral Consumption Forecasts

1980 - 2004

Mineral	1980	1985	1990	1995	2000	2004
Nickel[1]	666.62	759.44	852.27	945.09	1,037.92	1,130.74
Silver[2]	12,754.0	13.891.9	14,979.9	16,128.2	17,304.8	18,270.0
Lead[1]	3,833.81	4,366.29	4,786.26	5,518.71	6,208.33	6,817.91
Zinc[1]	6,457.2	7,867.39	9,277.58	10,687,76	12,097.95	13,508.14
Molybdenum[2]	106,725	126,008	148,407	175,849	210,262	244,198
Platinum[2]	246.4	360.7	512.6	731.5	1,040.7	1,376.6
Copper[1]	9,013.53	11,065.44	13,117.35	15,169.26	17,221.17	19,273.08
Iron[3]	735.8	844.1	952.4	1,060.6	1,168.9	1,277.2
Uranium[2*]	18,322	38,730	44,353			

1 000 metric tons
2 metric tons
3 000,000 metric tons
* western world only

Source: H. Strauss and E. Willauer
<u>Reports on Minerals</u>
(Submitted to the Royal Commission
on the Northern Environment May-Sept. 1981).

TABLE II-5

Mineral Prices

1950 - 1979

Mineral	1950	1955	1960	1965	1970	1975	1979
Gold[1]	35.00	35.00	35.00	35.00	36.19	146.19	307.6
Nickel[2]	0.45	0.65	0.74	0.79	1.29	2.09	2.72
Silver[3]	74.17	89.10	91.38	129.30	177.08	441.85	1,109.42
Lead[4]	13.3	15.14	11.98	16.00	15.69	21.52	52.64
Zinc[4]	14.6	12.8	13.5	15.0	15.8	38.89	37.3
Molybdenum[2]	0.54	1.05	1.25	1.55	1.72	2.49	7.76
Platinum[1]	77.68	85.06	83.21	98.04	132.50	169.87	352.33
Copper[4]	21.82	37.52	32.34	35.47	58.99	64.53	93.33
Iron[2]	7.70	10.10	11.45	10.55	10.80	17.89	25.47
Uranium[2]	8.92	12.51	8.99	7.25	7.41	23.68	42.57

[1] $ per ounce
[2] $ per pound
[3] ¢ per ounce
[4] ¢ per pound

Source: H. Strauss and E. Willauer
Report on Minerals
(Submitted to the Royal Commission
on the Northern Environment May-Sept., 1981).

TABLE II-6

Mineral Prices

1950 - 1979

in 1979 $U.S.

Mineral	1950	1955	1960	1965	1970	1975	1979
Gold[1]	108.07	94.96	84.32	77.96	65.53	190.21	307.61
Nickel[2]	138.24	174.99	178.27	175.03	234.04	271.83	271.52
Silver[3]	229.01	241.74	220.14	288.01	320.64	574.89	1,109.42
Lead[4]	41.07	41.08	28.79	35.64	28.41	28.00	52.64
Zinc[4]	45.08	34.73	32.40	33.41	28.65	50.60	37.30
Molybdenum[2]	1.67	2.85	3.01	3.45	3.11	3.24	7.76
Platinum[1]	239.85	230.78	200.46	218.38	239.92	221.02	352.33
Copper[4]	67.37	83.17	77.91	79.01	106.81	83.96	93.33
Iron[2]	23.77	27.40	27.58	23.50	19.56	23.28	25.47
Uranium[2]	8.92	-	8.99	7.25	7.41	23.68	42.57

[1] $ per ounce
[2] $ per pound
[3] ¢ per ounce
[4] ¢ per pound

TABLE II-7

Mineral Price Forecasts*

1980 - 2004

Mineral	1980	1985	1990	1995	2000	2004
Gold[1]	307	1,742	3,177	4,612	6,047	7,482
Nickel[2]	2.92	3.56	4.34	5.36	6.65	7.93
Silver[3]	1,075.79	1,208.64	1,909.27	3,073.58	4,975.22	7,362.04
Lead[4]	48.91	49.62	63.57	82.65	108,71	136.33
Zinc[4]	43.37	66.80	90.22	113.65	137.07	160.50
Molybdenum[2]	8.22	11.29	16.25	24.25	37.12	52.86
Platinum[5]	319.96	334.62	401.73	487.96	597.36	705.46
Copper[4]	105.11	128.64	151.88	184.38	226.27	267.70
Iron[2]	25.7	27.8	31.3	36.5	43.6	51.0
Uranium	33.49	17.89	14.97	14.97	16.18	17.68

* In Constant 1979 $ (U.S.)

1 $ per ounce

2 $ per pound

3 ¢ per ounce

4 ¢ per pound

5 $ per troy ounce

Source: H. Strauss and E. Willauer
<u>Report on Minerals</u>
(Submitted to the Royal Commission
on the Northern Environment May-Sept., 1981).

Figure V - 1

Internal Rate of Return Copper-Zinc

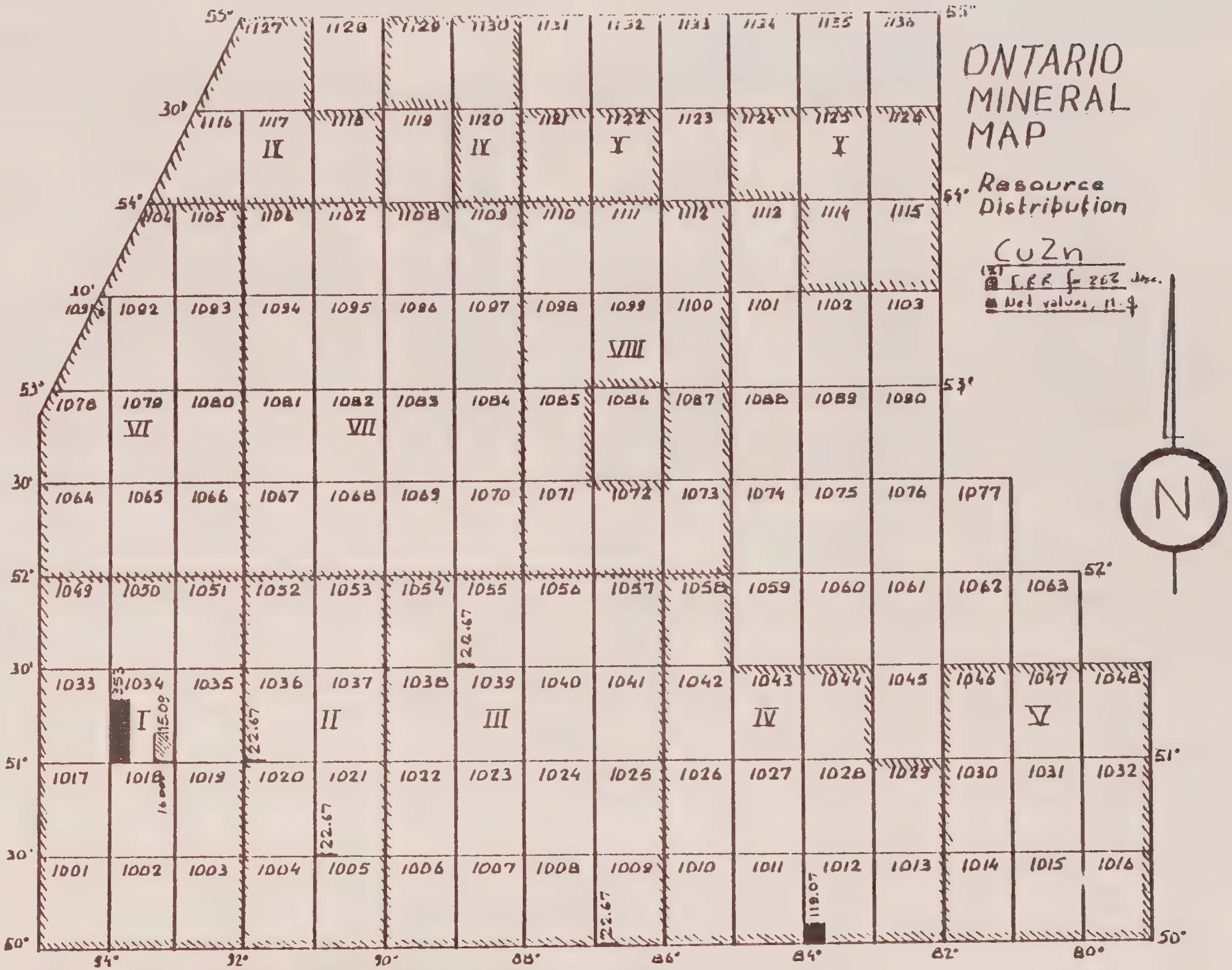


Figure V - 2

Internal Rate of Return Copper-Lead-Zinc

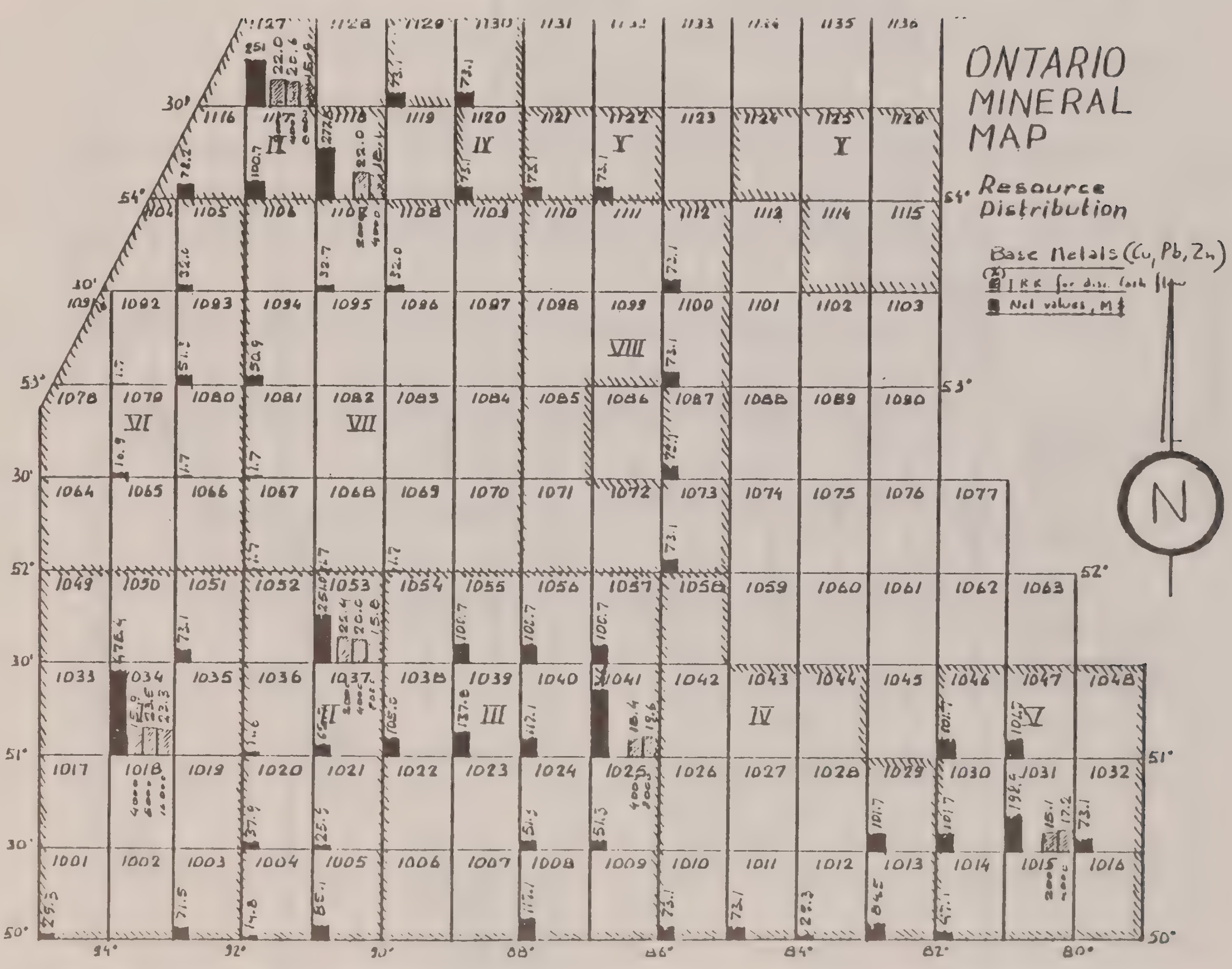


Figure V - 3

Internal Rate of Return Lead-Zinc

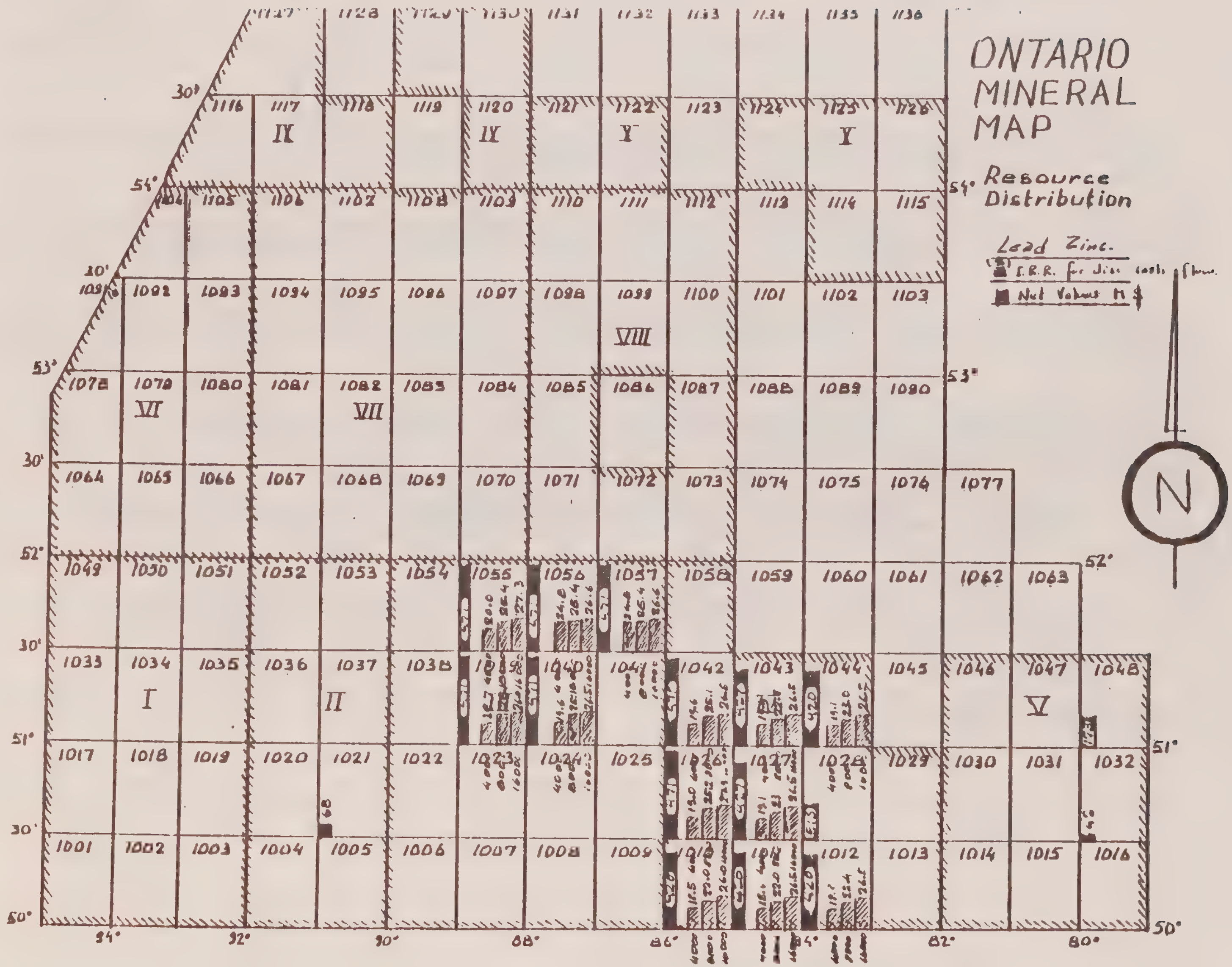


Figure V - 4

Internal Rate of Return Uranium

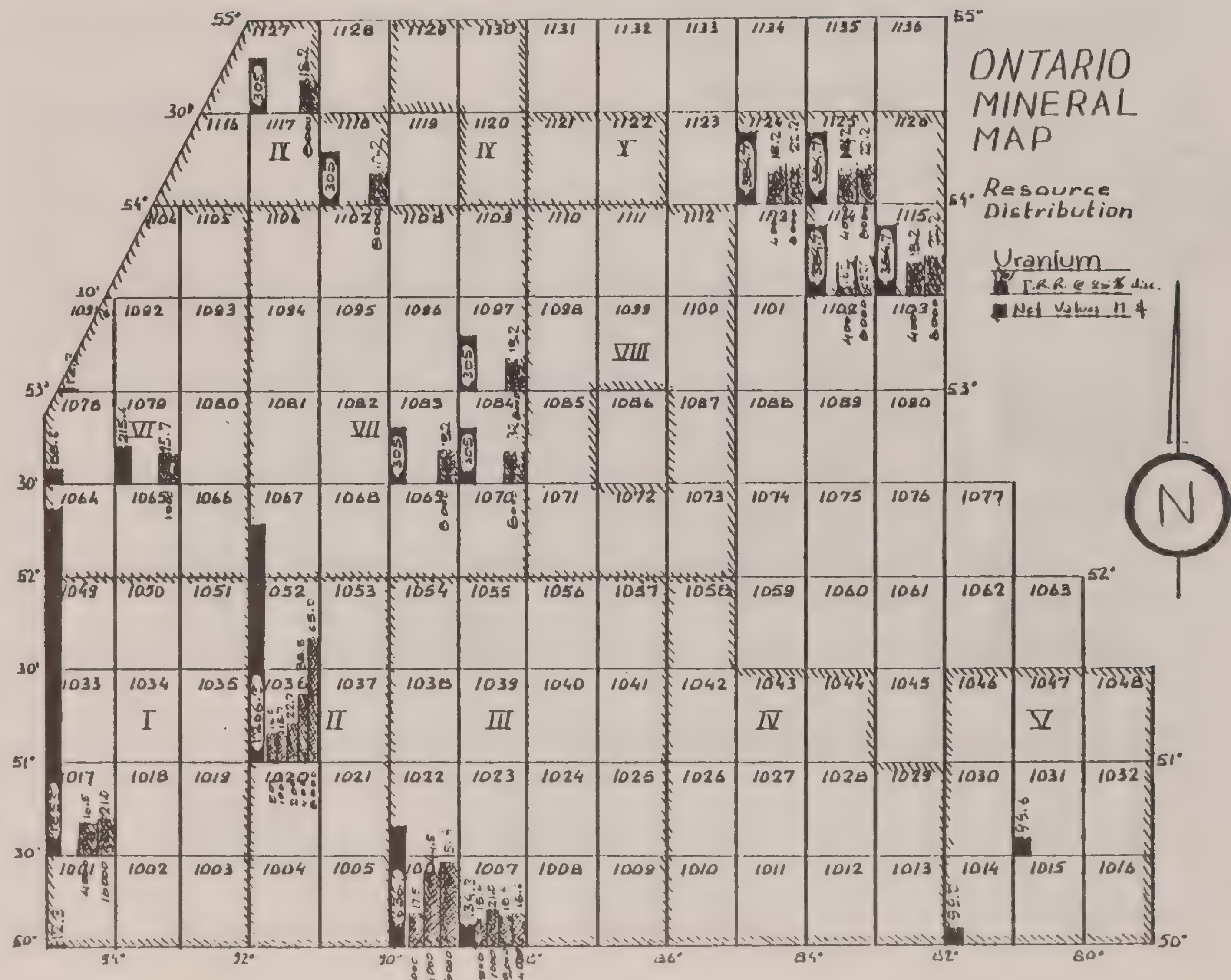


Figure V - 5

Internal Rate of Return Gold

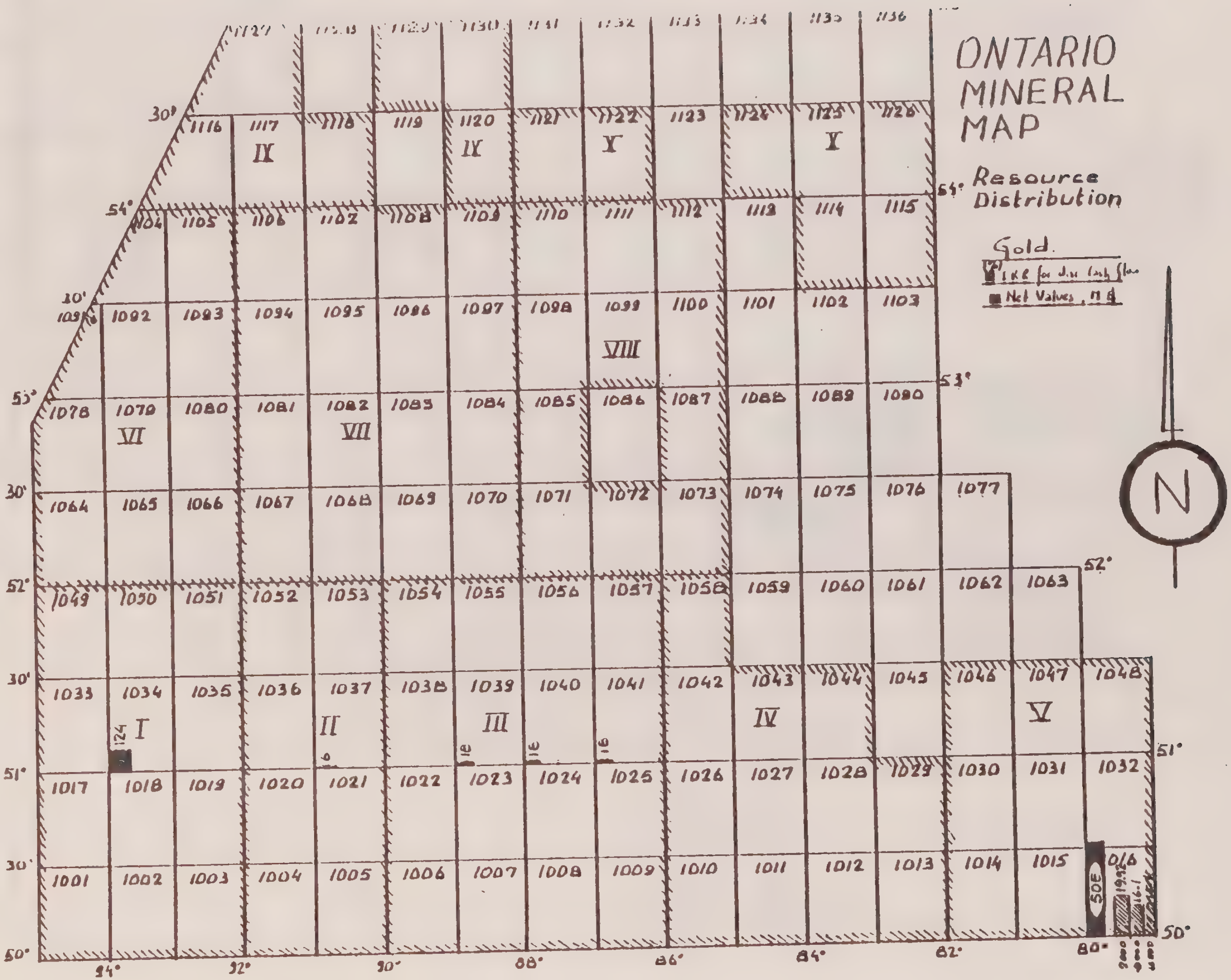


Figure V - 6

Internal Rate of Return Lithium-Columbium

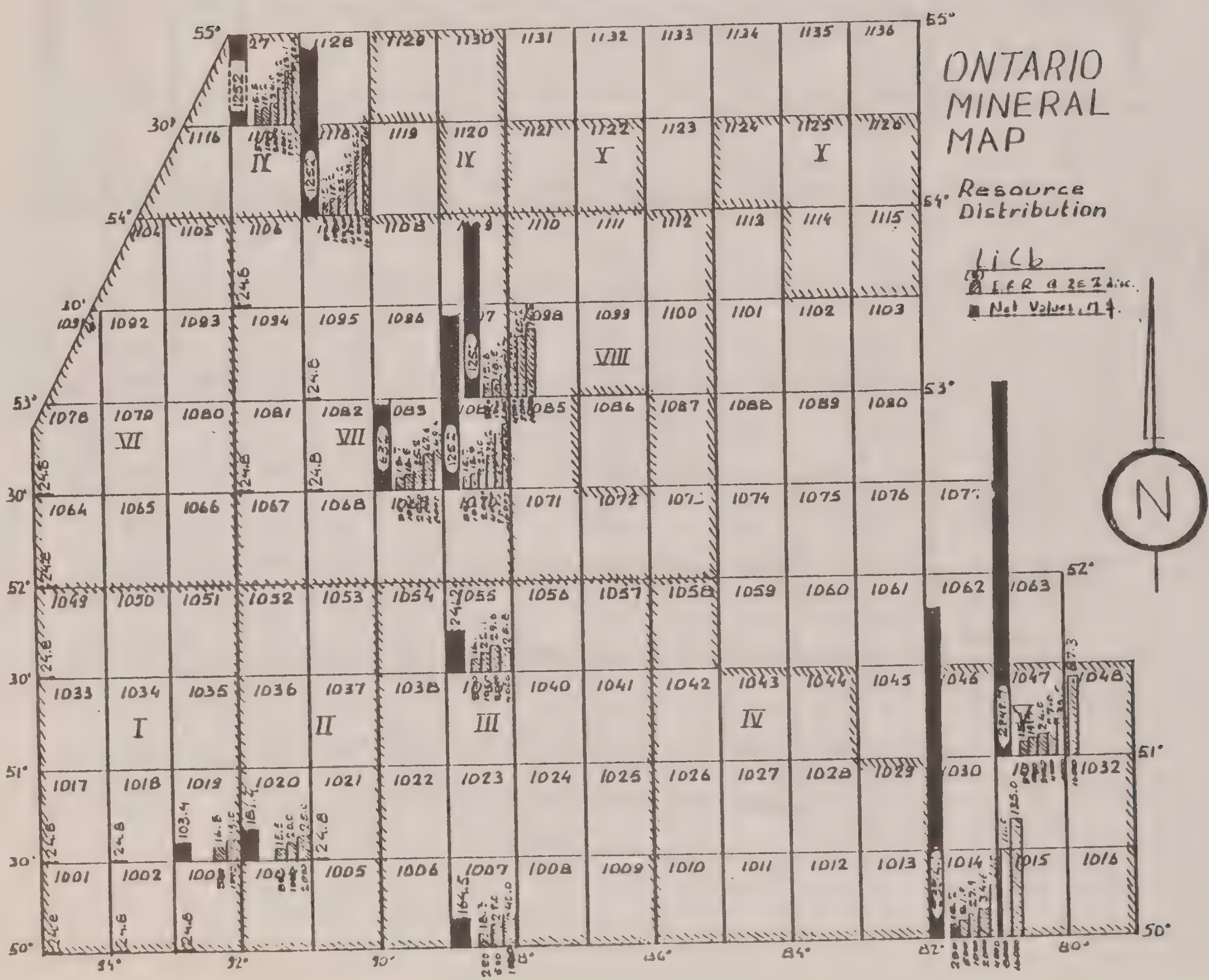
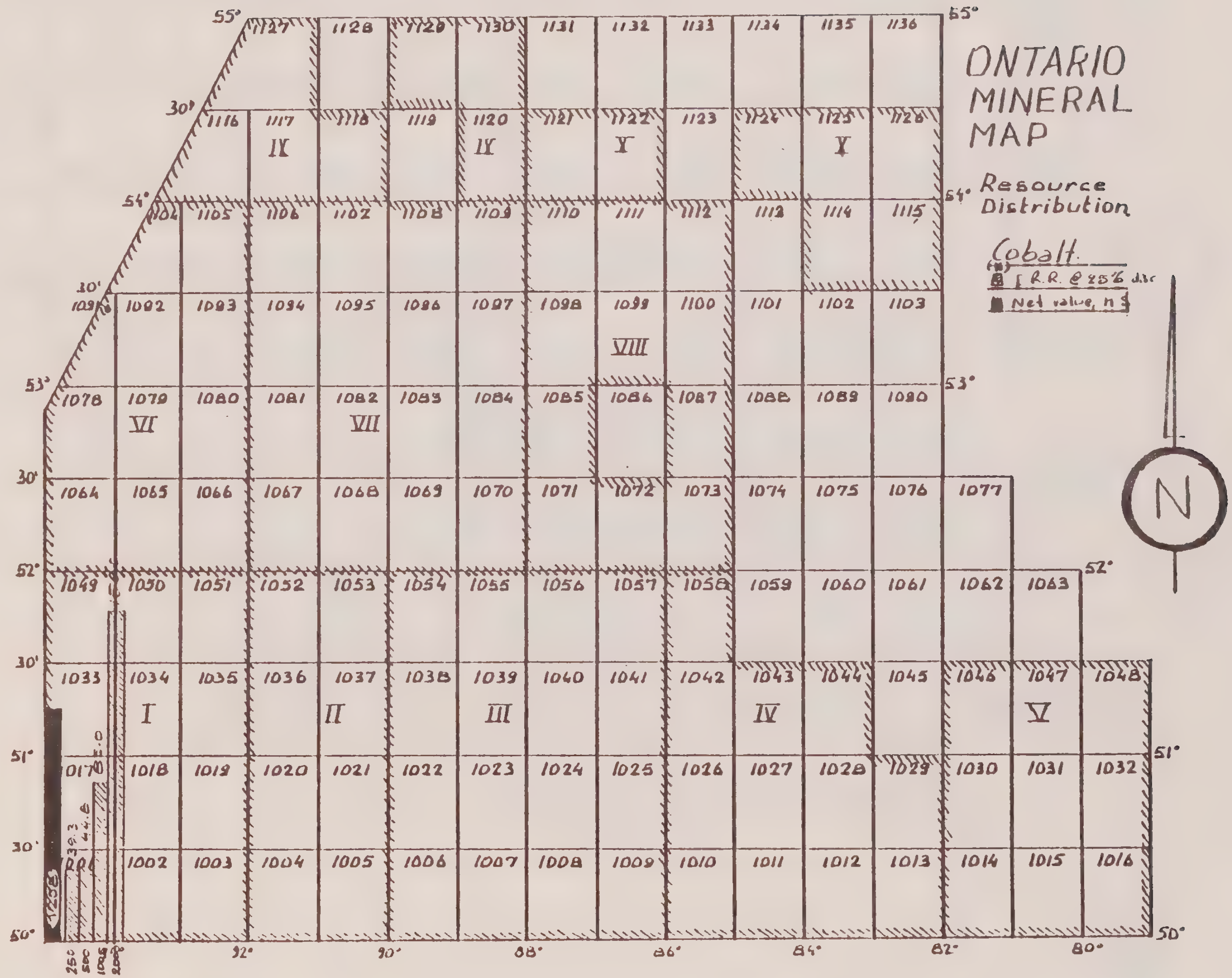


Figure V - 7

Internal Rate of Return Cobalt



APPENDIX B

SUMMARY

COUNTRY RISK RATINGS

SUMMARY

COUNTRY RISK RATINGS

COUNTRY	JAPANESE[1] COUNTRY RANKINGS	EUROMONEY[2] 1980 RANKINGS
AUSTRALIA	9	17
BRAZIL	26	47
CANADA	3	33
CHILE	21	41
COLOMBIA	39	40
DOMINICAN REPUBLIC	--	60
CHANA	60	--
INDIA	50	13
INDONESIA	33	24
JAPAN	--	--
LIBERIA	51	--
MEXICO	25	34
MOROCCO	55	52
PAPUA-NEW GUINEA	--	31
PERU	57	64
PHILIPPINES	22	45
RHODESIA (ZIMBABWE)	--	--
SOUTH AFRICA	32	61
SWEDEN	8	4
U.S.A.	1	--
WEST GERMANY	2	--
ZAIRE	69	--
ZAMBIA	--	--

COUNTRY	INSTITUTIONAL[3] INVESTOR 1979 RANKINGS	INSTITUTIONAL[4] INVESTOR 1980 RANKINGS
AUSTRALIA	10	9
BRAZIL	33	43
CANADA	5	5
CHILE	50	52
COLOMBIA	40	37
DOMINICAN REPUBLIC	71	75
GHANA	--	--
INDIA	49	54
INDONESIA	54	48
JAPAN	4	4
LIBERIA	68	69
MEXICO	25	25
MOROCCO	63	64
PAPUA-NEW GUINEA	--	--
PERU	76	72
PHILIPPINES	52	57
RHODESIA (ZIMBABWE)	83	80
SOUTH AFRICA	39	32
SWEDEN	14	13
U.S.A.	1	3
WEST GERMANY	2	2
ZAIRE	92	96
ZAMBIA	86	87

COUNTRY	WORLD POLITICAL[5] RISK RANKINGS	BERI[6] RANKINGS
AUSTRALIA	LOW	11
BRAZIL	MEDIUM	20
CANADA	LOW	6
CHILE	MEDIUM	--
COLOMBIA	MEDIUM	--
DOMINICAN REPUBLIC	MEDIUM	--
GHANA	--	--
INDIA	--	--
INDONESIA	--	--
JAPAN	LOW	4
LIBERIA	--	--
MEXICO	--	19
MOROCCO	MEDIUM	--
PAPUA-NEW GUINEA	--	--
PERU	HIGH	--
PHILIPPINES	HIGH	--
RHODESIA (ZIMBABWE)	--	--
SOUTH AFRICA	MEDIUM	12
SWEDEN	--	13
U.S.A	LOW	3
WEST GERMANY	LOW	1
ZAIRE	HIGH	--
ZAMBIA	HIGH	--

1. Reported in Engineering News Record, Vol 203, August 2, 1979, p. 17.
This rating involved a survey of 100 Japanese firms which have operated outside the country. A scale of 0 (worst) to 10 (best) was used to develop these rankings.

2. Source: Euromoney, February 1980, pp. 40-48.
This ranking analyses the credit rating of 75 countries in terms of the syndicated loan market. Each country's loans were weighted by volume, spread and maturity. The precise formula used is:

$$\text{Average weighted spread\%} - \frac{\text{E volume x spread x maturity}}{\text{E volume x maturity}}$$

Number of loans used includes the actual number of floating rate US dollar and Deutschemark loans used in the average weighted spread calculation. Loans with two or more tranches have been counted as two or more loans.

Average maturity refers to the sum of years divided by the total number of loans. Only loans included in the average weighted spread analysis have been taken into account.

Total number and total amount (public) refers to all loans in whatever currency signed in 1979 in $US million equivalent arranged for Governments public utilities, central banks, state owned banks, municipalities and any other borrower which carries a state guarantee.

3. Source: Institutional Investor, Vol.13, September 1979, pp. 243-246.

This evaluation of country creditworthiness was undertaken by Institutional Investor. It involved a survey of 50 of the world's leading international banks and interviews with an additional 40 international banks.

4. Source: Institutional Investor, Vol. 14, March 1980, pp. 63-65.

5. Source: The National Underwriter, Vol. 84, February 22, 1980, p. 55.

This ranking is done by Frost and Sullivan, a market research firm. A high risk rank is defined as a 45% or greater probability of a major alteration in government personnel would occur. A low risk is defined as a probability of less than 15% of such a change occuring. A medium risk assigns a probability of 15-45%.
Frost and Sullivan's forecast includes both an 18 month and a 5 year time perspective.

6. Source: A.H. Parbo, "Presidential Address - 50th Anzaas Congress", 14 May, 1980, p. 9.

The BERI index is published by the BERI Institute in Delaware U.S.A. A Delphi methodology is used involving about 100 experts and 15 criteria as a basis for judgement.

In this case, Mr. Parbo only reported the first 23 countries. Countries ranked lower than this were not specified and it is, therefore, impossible to reflect the more extensive list of countries in the actual BERI Report.

APPENDIX C

FORECASTING WORLD MINERAL PRICES, PRODUCTION AND CONSUMPTION

Dr. E.T. Willauer
Laurentian University

March 1981

FORECASTING WORLD MINERAL PRICES, PRODUCTION AND CONSUMPTION

FORECASTING WORLD MINERAL PRICES, PRODUCTION AND CONSUMPTION

Introduction

The primary objective of this chapter is to develop in as comprehensible a fashion as possible an econometric model of a world mineral market which can be used to forecast the world production, consumption and prices of ten minerals. The economic theory of a market for a mineral is considered in the first section of the chapter. The estimating equations and the method of estimation are explained in the second section. The last section contains the results from the estimation and simulation of the model. The summary statistics which are used to evaluate the performance of the model are described in the appendix to the chapter.

The formulation and development of the econometric model are, by necessity, mathematical. However, an introduction and summary are provided at the start of each section. The reader who is interested only in the method of approach and not the intricacies of the development, estimation and simulation of the model may read only the introduction.

The Theoretical Underpinning of the Model

Introduction and Summary

The econometric model used to forecast world mineral prices is based on traditional supply and demand analysis. It is assumed that minerals are traded in an essentially competitive market at market determined prices. At the equilibrium market determined price the quantity supplied of a particular mineral is equal to the quantity demanded of the mineral. The actual use of the mineral, consumption, is determined by the demand for the mineral.

Following traditional economic theory, it is hypothesized that the quantity supplied of a mineral is a function of its own real price, the real price of complement minerals in production and the level of technology. Since producers in extractive industries are generally unable to adjust immediately to changes in market conditions or technology, the supply function allows for partial adjustment.

Minerals are not demanded for themselves, but as inputs in the production of final goods. The quantity demanded of a mineral by the producers of final goods is, like any input, hypothesized to be a function of its own real price, the real price of substitute and complement inputs in the production of final goods, the level of final output and the level of technology. Since the producers of final goods are generally unable to adjust

instantaneously to changing market conditions, the demand function allows for lagged adjustment.

The equilibrium price of a mineral is determined in the market by the interaction of supply and demand. That is to say, the market price of a mineral is determined simultaneously with the quantity supplied and demanded of the mineral. Hence, the supply and demand functions are solved simultaneously for price.

Lastly, it is hypothesized that the quantity consumed of a mineral depends on the quantity demanded of a mineral. However, the two are not the same because of the use of secondary refined materials in consumption and the relationship between the two can change because of changes in technology.

Supply

Following traditional economic theory, the supply function for a mineral may be specified in its constant elasticity form as:

(1) $Q^*_{st} = \Theta_o P_t^{\Theta_1} T_t^{\Theta_2} R_t^{\Theta_3} e^{u_{st}}$

where, Q^*_s is the desired quantity supplied of the mineral, P is the real price of the mineral (nominal price relative to some price index), R is the real price of a complement mineral in production, T is the level of technology, t is time, u is the stochastic error term and e is the base of the natural log. Equation (1) can be written in its log form as:

(2) $\ln Q^*_{st} = \ln\Theta_o + \Theta_1 \ln Pt + \Theta_2 \ln Tt + \Theta_3 \ln Rt + u_{st}$

So far the specification of the supply function has been static. Yet, given the nature of mineral production, the length of time it takes to bring on-line new production facilities and the fixity of most of the inputs used in the production process, it is not possible to adjust supply immediately to changing market conditions. In order to explore the dynamic nature of the adjustment process, it is necessary to make a distinction between actual and desired quantity supplied. At any point in time, actual quantity supplied need not be equal to desired quantity supplied. However, in the long run when suppliers have time to adjust, actual quantity supplied will be brought into line with desired quantity supplied. Since desired quantity supplied is not directly observable, assume that a constant percentage of the discrepancy between actual and desired quantity supplied is eliminated within a single period. Thus:

$$(3) \quad Q_{st}/Q_{st-1} = (Q^*_{st}/Q_{st-1})^{\delta} \qquad 0 < \delta \leq 1$$

where Q_s is actual quantity supplied. Equation (3) can be expressed in log form as:

$$(4) \quad \ln Q_{st} - \ln Q_{st-1} = \delta \ln Q^*_{st} - \delta \ln Q_{st-1}$$

Substituting $\ln Q^*_{st}$ from equation (4) into equation (2) and rearranging:

$$(5) \quad \ln Q_{st} = \delta \ln \Theta_0 + \delta \Theta_1 \ln P_t + (1 - \delta) \ln Q_{st-1} + \delta \Theta_2 \ln T_t + \delta \Theta_3 \ln R_t + \delta u_{st}$$

or

$$(6) \quad \ln Q_{st} = \alpha_0 + \alpha_1 \ln P_t + \alpha_2 \ln Q_{st-1} + \alpha_3 \ln T_t + \alpha_4 \ln R_t + \varepsilon_{st}$$

where: $\alpha_0 = \delta \ln \Theta_0$

$$\alpha_1 = \delta\Theta_1$$

$$\alpha_2 = (1 - \delta)$$

$$\alpha_3 = \delta\Theta_2$$

$$\alpha_4 = \delta\Theta_3$$

$$\varepsilon_{st} = \delta u_{st}$$

Equation (6), which may be called the short-run supply function for a mineral, is the general form of the supply function employed in estimation. One desirable feature of the supply function is that α_1 may be interpreted as the short run price elasticity of supply, while $\alpha_1/(1 - \alpha_2)$ may be interpreted as the long run price elasticity. Standard economic theory predicts that α_1, α_3 and α_4 will be positive and that $0 \leq \alpha_2 < 1$.

Demand

Minerals are demanded as inputs in the production of final goods and not for final consumption. The demand for a mineral, like the demand for any input, is derived from the demand for the goods it helps to produce. The quantity demanded of a mineral is then a function of the level of final output which it helps to produce. However, a particular mineral is but one of a large number of inputs used in the production of final goods. In response to a change in the price of a mineral relative to the price of substitute inputs, the producers of final goods may adjust their input proportions, their output mix and their level of final goods production, and hence, their quantity demanded of the mineral.

While mineral demanders can adjust their quantity demanded to a change in price, they cannot respond instantaneously. Many production decisions must be made by the producers of final goods long before production actually occurs. Since future prices are not known with certainty, these decisions must be based on prices that are expected to exist when production occurs. While the theory of rational expectations predicts that the formation of price expectations will depend on many factors, the existing price will probably be the most important factor. The quantity demanded of a mineral then depends to some extent on the price that prevailed when the production decisions were made. This does not imply that the demand for a mineral in period t is unaffected by its price in period t. It is possible to adjust the quantity demanded of a mineral in the period to a change in its price in the period, but the adjustment can only be partial because some production decisions cannot be revised. Hence, the demand within a period depends on the price within the period as well as past prices.

Assuming a one period lag, the demand function for a mineral may be specified in its constant elasticity form as:

$$(7) \quad Q_{dt} = aP_t^{\beta_1} P_{t-1}^{\beta_2} T_t^{\beta_3} Y_t^{\beta_4} W_t^{\beta_5} e^{\varepsilon_{dt}}$$

where, Q_d is the quantity demanded of the mineral, P is the real price of the mineral (nominal price relative to some price index), W is the real price of a substitute or complement input in the production of final goods, T is the level of technology, Y is the level of final output, t is time, ε is the stochastic error term and e is the base of the natural log. Equation (7) may be expressed

in log form as:

(8) $\ln Q_{dt} = \beta_0 + \beta_1 \ln P_t + \beta_2 \ln P_{t-1} + \beta_3 \ln T_t + \beta_4 \ln Y_t + \beta_5 \ln W_t + \varepsilon_{dt}$

where, $\beta_0 = \ln a$

Equation (8) is the general form of the demand function employed in estimation. One desirable feature of the demand function is that β_1 may be interpreted as the price elasticity of demand while β_4 may be interpreted as the output elasticity. Standard economic theory predicts that β_1 will be negative, β_4 will be positive, and β_5 will be positive if the input is a substitute and negative if it is a complement. The sign of β_2 cannot be predicted because it depends on how expectations are formed. If high prices are expected to lead to lower prices in the future, β_2 will be positive, but if high prices are expected to lead to higher prices in the future, β_2 will be negative. Likewise, the sign of β_3 cannot be predicted since it depends on the nature of technological change.

Consumption

The quantity consumed of a mineral quite clearly depends on the quantity demanded of a mineral. However, the two are not the same because of the introduction of secondary refined materials in consumption. Likewise, the relationship between quantity consumed and quantity demanded can change over time because of changes in technology. This leads to the following consumption

function:

(9) $C_t = cQ_{dt}^{\gamma_1}T_t^{\gamma_2}e^{\varepsilon_{ct}}$

where, C is the quantity consumed of a mineral, Q_d is the quantity demanded, T is the level of technology, t is time, ε is the stochastic error term and e is the base of the natural log. Equation (9) can be written in its log form as:

(10) $\ln C_t = \gamma_0 + \gamma_1 \ln Q_{dt} + \gamma_2 \ln T_t + \varepsilon_{ct}$

where $\gamma_0 = \ln c$.

Equation (10) is the general form of the consumption function employed in estimation. Economic theory predicts that γ_1 and γ_2 will both be positive.

Equilibrium

A final equation is necessary to complete the model. The system of equations may be closed by noting that quantity demanded must be equal to quantity supplied in a competitive market. Thus, the following identity must hold:

(11) $Q_{dt} \equiv Q_{st} \equiv Q_t$.

The Empirical Model

Introduction and Summary

The final form of the model deviates slightly from the model presented in the previous section. The final specification of the model was determined by the model's ability to predict price. Thus, the decision to include a specific variable in an estimating equation was not based on the performance of the individual equation but on the overall performance of the model. Following this criterion, the price of related minerals was dropped from the model, the level of technology was dropped from the molybdenum and uranium models and the lagged response of iron ore producers was respecified. Also, dummy variables to account for the effect of market intervention were added to the gold and uranium models.

The parameters of the supply and demand equations were estimated using two stage least squares. Except in the case of molybdenum, platinum and uranium, the estimated equations were then solved simultaneously for predicted price. For molybdenum, platinum and uranium, the parameters of a "price equation" were estimated directly using ordinary least squares. Likewise, the parameters of the consumption equation were estimated using ordinary least squares.

Aspects of the Estimating Equations

Before considering the final form of the model, it is necessary to first discuss separately the deflator, the variables and lags.

Deflator In economics, it is not the nominal price of a mineral which is relevant but the real or relative price. On the supply side, suppliers are concerned with the price of the mineral relative to the price of other minerals and the costs of inputs used in mineral production. On the demand side, demanders are concerned with the price of the mineral relative to the price of substitute inputs in the production of final goods. The proper deflator should then be a good index of input costs on both the demand and supply side. While no existing index is perfect, it was felt that the U.S. implicit price deflator for gross national produce (GNP) was the best index. Also, the model performed better when this index rather than some other was used. However, in the case of uranium, the deflator failed to account for changing input costs, and consequently, nominal prices rather than real prices were used in the estimating equations for uranium.

Variables Except for uranium, the price for a mineral is the U.S. dollar price deflated by the U.S. GNP price index with 1979 as the base year. The United Nations index of real gross domestic product (GDP), excluding services for the world, is used as a proxy for the real value of final output. Further, it was assumed that technology has increased over the sample period at a

fairly constant rate. Therefore, time was used as a proxy for the level of technology.

Not all the variables in the model were retained in the final estimating equations. If technology used in the extraction of a mineral or in the production of final goods in which the mineral is an input are constant over the sample period, the proxy for the level of technology is an irrelevant variable. Likewise, if substitutability is difficult or impossible, or if minerals are weak complements, the price of a related mineral is an irrelevant variable. The decision to retain the level of technology or the price of a related mineral was not based on the performance of an individual equation but on the overall performance of the model; i.e., the model's ability to predict price. For example, if the inclusion of the price of a complement mineral in the supply equation reduced the estimated equation's residual variance but reduced the model's ability to predict price, it was dropped from the model. Following this criterion, the price of all related minerals were dropped from the model. The price of related minerals that were tested are given in Table 1. Likewise, the level of technology was dropped from the molybdenum and the uranium models and from the iron ore demand equation.

Additional variables were included in the gold and uranium models. A dummy variable was included in the supply equation for gold to account for the effect of a fixed nominal price for gold. Likewise, a dummy variable was included in the supply equation for uranium to account for the effect of the cartel.

<u>Lags</u> The lagged adjustment embodied in the model was not simply assumed but was tested for. A number of distributed lags, including an Almon polynomial lag, were also tried, but the hypothesized lagged adjustment led to the best overall performance of the model, except in the case of iron ore. For iron ore, the model performed best when the supply equation was specified with a one period price lag.

The Estimating Equations

For all minerals except iron ore, the empirical model may be conveniently summarized as:

(6a) Supply: $\ln Q_{st} = \alpha_0 + \alpha_1 \ln P_t + \alpha_2 \ln Q_{st-1} + \alpha_3 \ln T_t + \alpha_4 D_t + \varepsilon_{st}$

(8a) Demand: $\ln Q_{dt} = \beta_0 + \beta_1 \ln P_t + \beta_2 \ln P_{t-1} + \beta_3 \ln T_t + \beta_4 \ln Y_t + \varepsilon_{dt}$

(10) Consumption: $\ln C_t = \gamma_0 + \gamma_1 \ln Q_{dt} + \gamma_2 \ln T_t + \varepsilon_{ct}$

(11) Identity: $Q_{dt} \equiv Q_{st} \equiv Q_t$,

where the αs, βs and γs are parameters to be estimated and where:

Q = the quantity supplied and demanded of the mineral

C = the quantity consumed of the mineral

P = the U.S. dollar price of the mineral deflated by the GNP price index

Y = the U.N. index of real GDP excluding services for the world

T = the proxy, which is time, for the level of technology

D = the dummy variable. For gold D = 1 for the period 1951-1967 and D = 0 otherwise. For uranium D = 1 for the period 1974-1978 and D = 0 otherwise.

s = supply

d = demand

t = time

ε = the stochastic error term

The supply equations for gold and uranium are the only ones which have a dummy variable. The dummy variable is excluded from the supply equations for the remaining minerals. The proxy for the level of technology is excluded from the empirical model for uranium and molybdenum.

Price and quantity are determined simultaneously in the model. Substituting (6a) and (8a) into (11) and solving for price gives the reduced form:

(12) reduced form: $\ln P_t = \Pi_0 + \Pi_1 \ln P_{t-1} + \Pi_2 \ln Q_{t-1} + \Pi_3 \ln T_t + \Pi_4 \ln D_t + \Pi_5 \ln Y_t + \varepsilon_t$

where: $\Pi_0 = (\beta_0 - \alpha_0)/(\alpha_1 - \beta_1)$

$\Pi_1 = \beta_2/(\alpha_1 - \beta_1)$

$\Pi_2 = -\alpha_2/(\alpha_1 - \beta_1)$

$\Pi_3 = (\beta_3 - \alpha_3)/(\alpha_1 - \beta_1)$

$\Pi_4 = -\alpha_4/(\alpha_1 - \beta_1)$

$\Pi_5 = \beta_4/(\alpha_1 - \beta_1)$

$\varepsilon_t = (\varepsilon_{dt} - \varepsilon_{st})/(\alpha_1 - \beta_1)$

While the consumption equation and the identity are the same for iron ore as for the other minerals, the supply and demand equations are different. Thus:

(6b) supply: $\ln Q_{st} = \alpha_0 + \alpha_1 \ln P_t + \alpha_2 \ln P_{t-1} + \alpha_3 \ln T_t + \varepsilon_{st}$

(8b) demand: $\ln Q_{dt} = \beta_0 + \beta_1 \ln P_t + \beta_2 \ln P_{t-1} + \beta_3 \ln Y_t + \varepsilon_{dt}$

The reduced form for iron ore is also different in that now:

$$\Pi_1 = (\beta_2 - \alpha_2)/(\alpha_1 - \beta_1)$$

$$\Pi_2 = 0$$

$$\Pi_3 = -\alpha_3/(\alpha_1 - \beta_1)$$

$$\Pi_4 = 0$$

$$\Pi_5 = \beta_3/(\alpha_1 - \beta_1)$$

Method of Estimation

The mineral market model is a block-recursive system of equations. The group of equations can be broken up into blocks of equations in such a way that equations within each block are simultaneous, but the blocks are recursive. The first block of equations contains the supply equation and the demand equation. In general, within the block are two endogenous variables (Q_t,P_t), two lagged endogenous variables (Q_{t-1},P_{t-1}) and three exogenous variables (T_t,Y_t,D_t). Notice that both equations are identified, but only in the case of iron ore are both equations just identified.

The parameters of the supply and demand equations were estimated using two stage least squares. These parameter estimates were then used to estimate the parameters of the reduced form equation. However, this estimating procedure did not perform well for molybdenum, platinum or uranium. It was found that for these three minerals there was almost perfect collinearity between the predetermined variables in the demand equation and the instrumental variable used for price, and consequently, the parameters of the demand equation could not be estimated with any

acceptable degree of precision. Hence, for these three minerals, the parameters of the reduced form equation were estimated directly using ordinary least squares.

The second block contains only the consumption equation. Within the block is one endogenous variable (C_t), one endogenous variable determined outside the block (Q_t) and one exogenous variable (T_t). Since Q_t is predetermined, the parameters of the consumption equation were estimated using ordinary least squares. Autocorrelation was corrected for using the Hildreth-Lu procedure.

Parameter Estimates, Simulation and Forecasting

Introduction and Summary

The parameters of the model introduced in the previous section were estimated using yearly data for the period 1951-1979, except in the case of uranium. For uranium the sample period was 1957-1979. Except for the price coefficient in the supply equation for gold, the sign of the estimated parameters are as predicted by the theory. However, even if the sign of the parameter estimates are correct and all the individual equations fit the data well, there is no guarantee that the model as a whole will adequately reproduce the data series and be useful for forecasting purposes. The performance of the model was checked by performing an historical simulation over the sample period and examining how closely price, quantity and consumption tracked their corresponding historical data series. The results were very good, suggesting that the model should do well in forecasting.

Parameter Estimates

The parameter estimates along with their standard errors (in parentheses), the coefficient of determination (R^2), the standard error of estimate (SEE) and the Durbin-Watson statistic (DW) are given in Tables 2 - 11. It should be noted that the Durbin-Watson statistic is an inappropriate test statistic for first-order serial correlation in the supply equation. As is

customary, the ordinary least squares estimates are provided for comparison with the two stage least squares estimates. The parameters of the consumption equation could not be estimated for gold, molybdenum, platinum or uranium because of a lack of data on consumption.

Except for the price coefficient in the supply equation for gold, the two stage least squares estimates are of the correct sign in those cases where the sign could be predicted. It should be recalled that the parameter estimates can be interpreted as estimated elasticities. For example, it is estimated that a 1% increase in world GDP would increase the demand for lead by .81% and a 1% increase in the price of lead would increase the supply of lead by .11% in the short run and .29% in the long run.

The parameter estimates of the supply and demand equations were substituted into the reduced form equation to give predicted price (except in the case of molybdenum, platinum and uranium). Various summary statistics which are used to evaluate how closely the model fits the data on price are provided in Table 12. The MSE, r and the U statistics are defined in the appendix to the chapter. R is the correlation between actual price and predicted price. Overall, the model fits the data closely for all ten minerals.

Simulation and Forecasting

In the case of a single equation, there exists a set of statistical tests that can be used to judge the significance of

the equation and its individual estimated parameters. However, the system of equations will have a dynamic structure that is much richer than any one of the individual equations. Thus, even if all the individual equations fit the data well, there is no guarantee that the model as a whole will adequately reproduce the data series. An historical simulation provides a check on the model's ability to track the historical data series and consequently, to forecast.

In the simulation process the model is solved for the time path of price, quantity and consumption given the estimated parameters of the model, time series for world GDP and technology and initial values for price and quantity. For example, consider the model for lead and let t be the base period. Given the values of the endogenous variables determined in the previous period, P_{t-1} and Q_{t-1}, and the values of the exogenous variables, Y_t and T_t, the reduced form equation may be solved for simulated price, $\hat{P}_t$. Given simulated price, $\hat{P}_t$, and Q_{t-1}, Y_t and T_t the supply equation may be solved for simulated quantity, $\hat{Q}_t$. The simulated values for price and quantity for period t have now been solved for.

The same process can be used to solve for the simulated values of price and quantity in period t + 1. Given the simulated values of price and quantity for period t, $\hat{P}_t$ and $\hat{Q}_t$, and Y_{t+1} and T_{t+1}, the reduced form may be solved for simulated price, $\hat{P}_{t+1}$. Given simulated price, $\hat{P}_{t+1}$, and $\hat{Q}_t$, Y_{t+1} and T_{t+1} the supply equation may be solved for simulated quantity, $\hat{Q}_{t+1}$. The simulated values for price and quantity for period t+1 have now been solved

for. The simulation process will continue until period t + n, where the model is simulated for n + 1 periods.

The actual historical simulation begins in 1951 (1957 for uranium) and runs forward until 1979. Historical values in 1950 (1956 for uranium) are supplied as initial conditions for price and quantity, and historical series beginning in 1951 and ending in 1979 are used for world GDP and technology.

A comparison of the historical values of price, quantity and consumption with their simulated values provides a useful test of the validity of the model. The time path of the simulated values and the historical values are shown graphically in Figures 1-26. However, the summary statistics described in the Appendix provide a much better guide to the performance of the model than a visual examination of the graphs. These are given in Tables 13-15. The performance of the model is very good considering the model was simulated over 29 years (23 for uranium) and the model should do well in forecasting.

Forecasting simply involves the simulation of the model forward in time beyond the estimation period. Of course, before a forecast can be made, a time series covering the entire forecast period for world GDP and technology must exist. The values for future world GDP were based on United Nation predictions while time is again used as a proxy for technology. The forecasted values for price, quantity and consumption for the period 1980-2004 are given in the chapters for the individual minerals. Even though the historical simulation for gold was very good,

the forecast for gold, especially past 1990, should be interpreted with caution because of the apparent instability of the model for gold.

Appendix

Let A_t be the actual value of a variable in period t and B_t be the predicted value for the same period. The actual relative change is $a_t = (A_t - A_{t-1})/A_{t-1}$ and the predicted relative change is $b_t = (B_t - A_{t-1})/A_{t-1}$. The mean-squared error may then be defined as:

$$MSE = \sum_{t=1}^{N} (b_t - a_t)^2/N$$

Theil has shown that the MSE may be decomposed into the following set of components:

$$U_M = (\bar{b} - \bar{a})^2/MSE$$

$$U_R = (S_b - rS_a)^2/MSE$$

$$U_D = (1 - r^2)S_a^2/MSE$$

where, $\bar{b}$ and $\bar{a}$ are mean values, S_b and S_a are standard deviations, and r is the correlation between b and a. Notice that $U_M + U_R + U_D = 1$.

The interpretation of the decomposition is straightforward. Consider the regression of actual on predicted values:

$$A_t = \propto + \beta B_t$$

U_M will be zero if $\hat{\propto} = 0$, U_R will be zero if $\hat{\beta} = 1$ and U_D will be one if $\hat{\propto} = 0$ and $\hat{\beta} = 1$. Notice that the decomposition U_M, U_R and U_D yield information on the possible inadequacies of the forecasts.

Next, consider the following inequality coefficient

$$U_T = (MSE/(\sum_{t=1}^{N} A^2{}_t/N))^{.5}$$

which is commonly called the Theil U statistic. Theil has shown that if B_t is a perfect forecast for A_t, U_T is equal to zero. Notice that U_T provides a useful measure of the accuracy of the forecasts.

TABLE 1 - Some Related Minerals in Supply and Demand

	RELATED MINERAL	
MINERAL	SUPPLY	DEMAND
Silver	Copper	Gold
Gold	Nickel	Silver
Copper	Nickel	Tin
Iron Ore	Aluminum	Steel
Molybdenum	—	Steel
Nickel	Copper	Steel
Lead	Zinc	Zinc
Platinum	Nickel	Copper
Uranium	—	—
Zinc	Lead	Aluminum

TABLE 2 - Parameter Estimates for Silver

	Ordinary Least Squares			Two Stage Least Squares	
	Supply	Demand	Con-sumption	Supply	Demand
P_t	.065 (.045)	-.106 (.082)		.126 (.058)	-.906 (.688)
P_{t-1}		.110 (.097)			.672 (.514)
Q_t			.171 (.275)		
Q_{t-1}	.775 (.115)			.691 (.128)	
T_t	.036 (.029)	-.167 (.069)	.338 (.086)	.034 (.030)	-.387 (.240)
Y_t		.778 (.157)			1.401 (.625)
Constant	1.038 (.598)	3.811 (.292)	4.785 (1.669)	1.239 (.630)	3.204 (.825)
R^2	.932	.918	.958	.927	.590
SEE	.061	.068	.097	.063	.152
DW	1.971	.978	2.143	1.722	1.428
$\hat{\rho}$			.662		

Notes: Standard errors in parenthesis. R^2 = coefficient of determination,

SEE = standard error of estimate, DW = Durbin-Watson statistic,

$\hat{\rho}$ = the estimated first-order coefficient of auto correlation.

TABLE 3 - Parameter Estimaters for Gold

	Ordinary Least Squares		Two Stage Least Squares	
	Supply	Demand	Supply	Demand
P_t	-.104 (.020)	-.190 (.072)	-.112 (.026)	-.835 (.413)
P_{t-1}		-.165 (.075)		.413 (.379)
Q_{t-1}	.702 (.059)		.684 (.069)	
T_t	.077 .017	.192 (.053)	.082 (.019)	.056 (.138)
D_t	-.003 (.001)		-.003 (.001)	
Y_t		.078 (.102)		.435 (.301)
Constant	2.375 (.446)	7.763 .226	2.527 (.543)	6.966 (.670)
R^2	.987	.925	.987	.672
SEE	.022	.053	.022	.110
DW	1.743	.609	1.707	1.080

Notes: See Table 2

TABLE 4 - Parameter Estimates for Copper

	Ordinary Least Squares			Two Stage Least Squares	
	Supply	Demand	Con-sumption	Supply	Demand
P_t	.107 (.073)	-.057 (.120)		.084 (.113)	-.953 (.533)
P_{t-1}		.026 (.118)			.497 (.335)
Q_t			.868 (.150)		
Q_{t-1}	.845 (.066)			.844 (.066)	
T_t	.077 (.040)	.092 (.057)	.037 (.081)	.078 (.041)	.035 (.109)
Y_t		.860 (.099)			.988 (.194)
Constant	.677 (.563)	4.795 (.543)	1.149 (1.089)	.782 (.683)	6.290 (1.280)
R^2	.988	.978	.989	.988	.927
SEE	.050	.068	.062	.050	.125
DW	1.708	.686	1.650	1.739	1.504
$\hat{\rho}$			.638		

Notes: See Table 2.

TABLE 5 - Parameter Estimates for Iron Ore

	Ordinary Least Squares			Two Stage Least Squares	
	Supply	Demand	Consumption	Supply	Demand
P_t	.327 (.300)	-.045 (.230)		6.448 (6.842)	-2.666 (2.404)
P_{t-1}	-1.127 (.296)	-.212 (.236)		-6.319 (5.838)	2.020 (2.073)
Q_t			.753 (.072)		
T_t	.519 (.029)		1.077 (.043)	.638 (.179)	
Y_t		1.001 (.043)			.937 (.121)
Constant	9.192 (.542)	4.661 (.558)	2.063 (.477)	5.921 (4.254)	6.166 (1.929)
R^2	.959	.975	.993	.285	.849
SEE	.095	.074	.040	.401	.184
DW	1.099	1.126	1.693	2.059	2.031
$\hat{\rho}$			.461		

Notes: See Table 2.

TABLE 6 - Parameter Estimates for Molybdenum

	Ordinary Least Squares			Two Stage Least Squares
	Supply	Demand	Reduced Form	Supply
P_t	-.004 (.106)	-.130 (.157)		.046 (.129)
P_{t-1}		.020 (.182)	.945 (.135)	
Q_{t-1}	.918 (.059)		-.057 (.210)	.899 (.065)
Y_t		1.278 (.069)	.146 (.288)	
Constant	.580 (.298)	1.051 (.221)	-.145 (.324)	.639 (.311)
R^2	.944	.963	.827	.943
SEE	.128	.106	.135	.129
DW	2.318	1.323	1.180	2.261

Notes: See Table 2.

TABLE 7 - Parameter Estimates for Nickel

	Ordinary Least Squares		Two Stage Least Squares		
	Supply	Demand	Consumption	Supply	Demand
P_t	.298 (.246)	.394 (.392)		.126 (.316)	-3.624 (4.363)
P_{t-1}		-.577 (.367)			1.827 (2.691)
Q_t			.459 (.127)		
Q_{t-1}	.578 (.154)			.626 (.165)	
T_t	.235 (.115)	.313 (.112)	.298 (.099)	.230 (.116)	-.065 (.478)
Y_t		.868 (.246)			2.072 (1.400)
Constant	.369 (1.068)	2.525 (1.224)	2.450 (.573)	1.011 (1.302)	7.117 (5.642)
R^2	.956	.957	.945	.955	.767
SEE	.126	.127	.089	.127	.295
DW	1.848	1.113	2.000	2.000	1.970
$\hat{\rho}$			.708		

Notes: See Table 2.

TABLE 8 - Parameter Estimates for Lead

	Ordinary Least Squares			Two Stage Least Squares	
	Supply	Demand	Consumption	Supply	Demand
P_t	.014 (.059)	-.168 (.088)		.108 (.080)	-.743 (.591)
P_{t-1}		.052 (.099)			.463 (.441)
Q_t			.052 (.197)		
Q_{t-1}	.658 (.140)			.628 (.147)	
T_t	.111 (.055)	.051 (.063)	.275 (.082)	.137 (.059)	-.128 (.206)
Y_t		.502 (.098)			.808 (.345)
Constant	2.374 (.963)	6.060 (.323)	6.830 (1.412)	2.217 (1.014)	5.829 (.583)
R^2	.954	.959	.986	.949	.886
SEE	.059	.057	.061	.062	.095
DW	2.122	1.242	2.057	1.950	1.536
$\hat{\rho}$			.864		

Notes: See Table 2.

TABLE 9 - Parameter Estimates for Platinum

	Ordinary Least Squares			Two Stage Least Squares
	Supply	Demand	Reduced Form	Supply
P_t	.379 (.236)	.254 (.354)		.462 (.393)
P_{t-1}		.132 (.388)	.481 (.211)	
Q_{t-1}	.632 (.134)		-.047 (.120)	.610 (.158)
T_t	.396 (.164)	.553 (217)	-.263 (.127)	.424 (.195)
Y_t		1.059 (.367)	.579 (.233)	
Constant	.688 (1.191)	2.148 (1.819)	1.570 (1.004)	.388 (1.647)
R^2	.966	.953	.512	.966
SEE	.165	.198	.114	.165
DW	1.662	.952	1.347	1.630

Notes: See Table 2

TABLE 10 - Parameter Estimates for Uranium

	Ordinary Least Squares			Two Stage Least Squares
	Supply	Demand	Reduced Form	Supply
Pt	.269 (.081)	-.174 (.208)		.314 (.086)
P_{t-1}		.627 (.212)	.825 (.068)	
Q_{t-1}	.667 (.116)		.022 (.111)	.640 (.118)
D_t	-.234 (.128)		.514 (.100)	-.290 (.134)
Y_t		-.466 (.162)	.085 (.119)	
Constant	1.272 (.584)	6.453 (.629)	-.131 (.807)	1.327 (.589)
R^2	.796	.663	.964	.792
SEE	.155	.199	.142	.156
DW	1.036	.829	2.014	1.102

Notes: See Table 2

TABLE 11 - Parameter Estimates for Zinc

	Ordinary Least Squares			Two Stage Least Squares	
	Supply	Demand	Con-sumption	Supply	Demand
P_t	.039 (.055)	-.107 (.104)		.069 (.071)	-1.122 (.769)
P_{t-1}		-.057 (.094)			.423 (.405)
Q_t			.693 (.141)		
Q_{t-1}	.843 (.096)			.819 (.103)	
T_t	.061 (.047)	-.039 (.082)	.155 (.064)	.074 (.051)	-.395 (.315)
Y_t		.862 (.138)			1.492 (.550)
Constant	1.040 (.618)	5.408 (.275)	2.077 (1.018)	1.100 (.628)	5.597 (.627)
R^2	.979	.968	.980	.979	.839
SEE	.052	.066	.061	.052	.147
DW	1.852	.815	2.016	1.757	1.366
$\hat{\rho}$			.378		

Notes: See Table 2.

TABLE 12 - Summary Statistics for Price

Mineral	R	r	MSE	U_M	U_R	U_D	U_T
Silver	.9265	.5183	.0006	.0002	.0059	.9939	.0043
Gold	.9400	.5501	.0008	.0000	.0147	.9853	.0060
Copper	.6704	.6196	.0004	.0001	.0091	.9907	.0050
Iron Ore	.9028	.4007	.0003	.0011	.0179	.9810	.0061
Molybdenum	.9094	.2003	.0265	.0019	.0051	.9930	.1388
Nickel	.9370	.5250	.0001	.0002	.0462	.9536	.0021
Lead	.8453	.5282	.0012	.0001	.0142	.9857	.0099
Platinum	.7155	.5654	.0004	.0002	.0007	.9991	.0036
Uranium	.9819	.8644	.0028	.0003	.0260	.9737	.0214
Zinc	.8258	.6131	.0010	.0008	.0122	.9870	.0090

Notes: See the Appendix.

TABLE 13 - Summary Statistics for Price - Simulation

Mineral	r	MSE	U_M	U_R	U_D	U_T
Silver	.3918	.0717	.0133	.4135	.5732	.0007
Gold	.5933	.0326	.0022	.3039	.6938	.0014
Copper	.5640	.0137	.0075	.2331	.7593	.0014
Iron	.4390	.0111	.0305.	.6457	.3238	.0043
Molybdenum	.2502	.1347	.0637	.7583	.1780	.1069
Nickel	.5680	.0057	.0014	.3550	.6435	.0004
Lead	.4135	.0301	.0126	.3982	.5892	.0052
Platinum	.5427	.0142	.0020	.1495	.8485	.0005
Uranium	.8714	.0245	.0076	.0846	.9078	.0080
Zinc	.5074	.0235	.0021	.2846	.7133	.0044

Notes: See the Appendix.

TABLE 14 - Summary Statistics for Production - Simulation

Mineral	r	MSE	U_M	U_R	U_D	U_T
Silver	.5515	.0040	.0037	.1739	.8224	.0001
Gold	.7675	.0008	.0008	.2017	.7975	.0000
Copper	.5168	.0040	.0033	.3901	.6060	.0000
Iron	.6832	.0047	.0049	.1002	.8949	.0000
Molybdenum	.4573	.0308	.0725	.5200	.4074	.0003
Nickel	.6198	.0186	.0000	.3300	.6699	.0003
Lead	.5007	.0044	.0003	.2003	.7993	.0000
Platinum	.5416	.0486	.0029	.2316	.7655	.0000
Uranium	.3843	.0678	.0066	.5225	.4709	.0009
Zinc	.4114	.0055	.0003	.5085	.4911	.0000

Notes: See the Appendix.

TABLE 15 - Summary Statistics for Consumption - Simulation

Mineral	r	MSE	U_M	U_R	U_D	U_T
Silver	.2601	.0129	.0123	.3247	.6630	.0001
Gold	---	---	---	---	---	---
Copper	.5334	.0042	.0029	.0220	.9750	.0000
Iron	.4574	.0149	.0046	.7814	.2140	.0000
Molybdenum	---	---	---	---	---	---
Nickel	.2525	.0149	.0320	.3497	.6183	.0003
Lead	.3790	.0065	.0199	.6367	.4434	.0000
Platinum	---	---	---	---	---	---
Uranium	---	---	---	---	---	---
Zinc	.5432	.0029	.0049	.0347	.9604	.0000

Notes: See the Appendix

LEGEND FOR FIGURES 1 to 26

Simulated Values of Prices, Supply and Consumption	o—o—o—o—o—□
Actual Prices	* * * * *
Actual Supply	* * * * *
Actual Consumption	* * * * *

FIGURE 1

SIMULATED AND ACTUAL SILVER PRICES IN CONSTANT 1979 U.S. CENTS PER TROY OUNCE FOR THE YEARS 1951 TO 1979

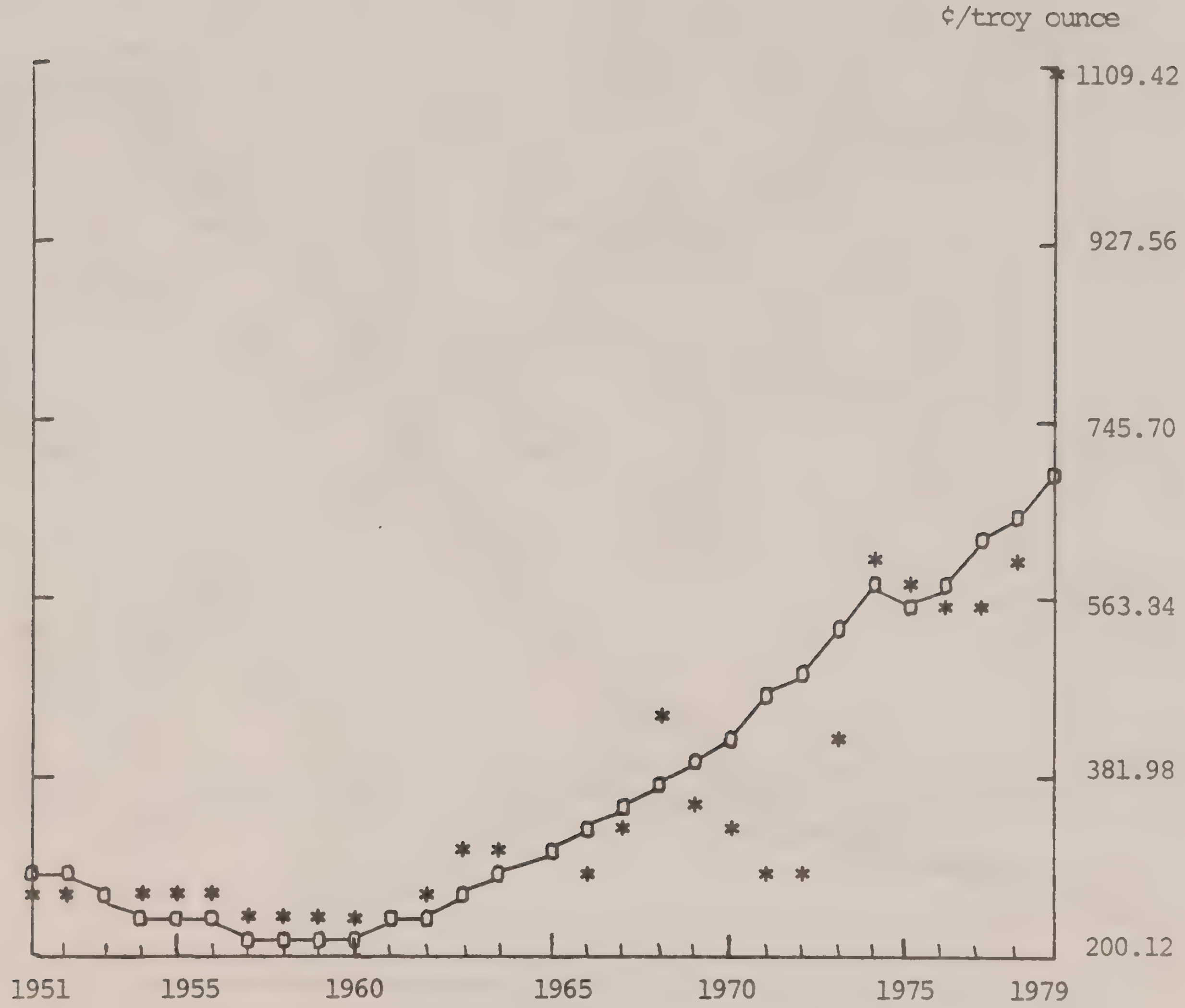


FIGURE 2

SIMULATED AND ACTUAL WORLD SUPPLY OF SILVER FOR

THE YEARS 1951 TO 1979

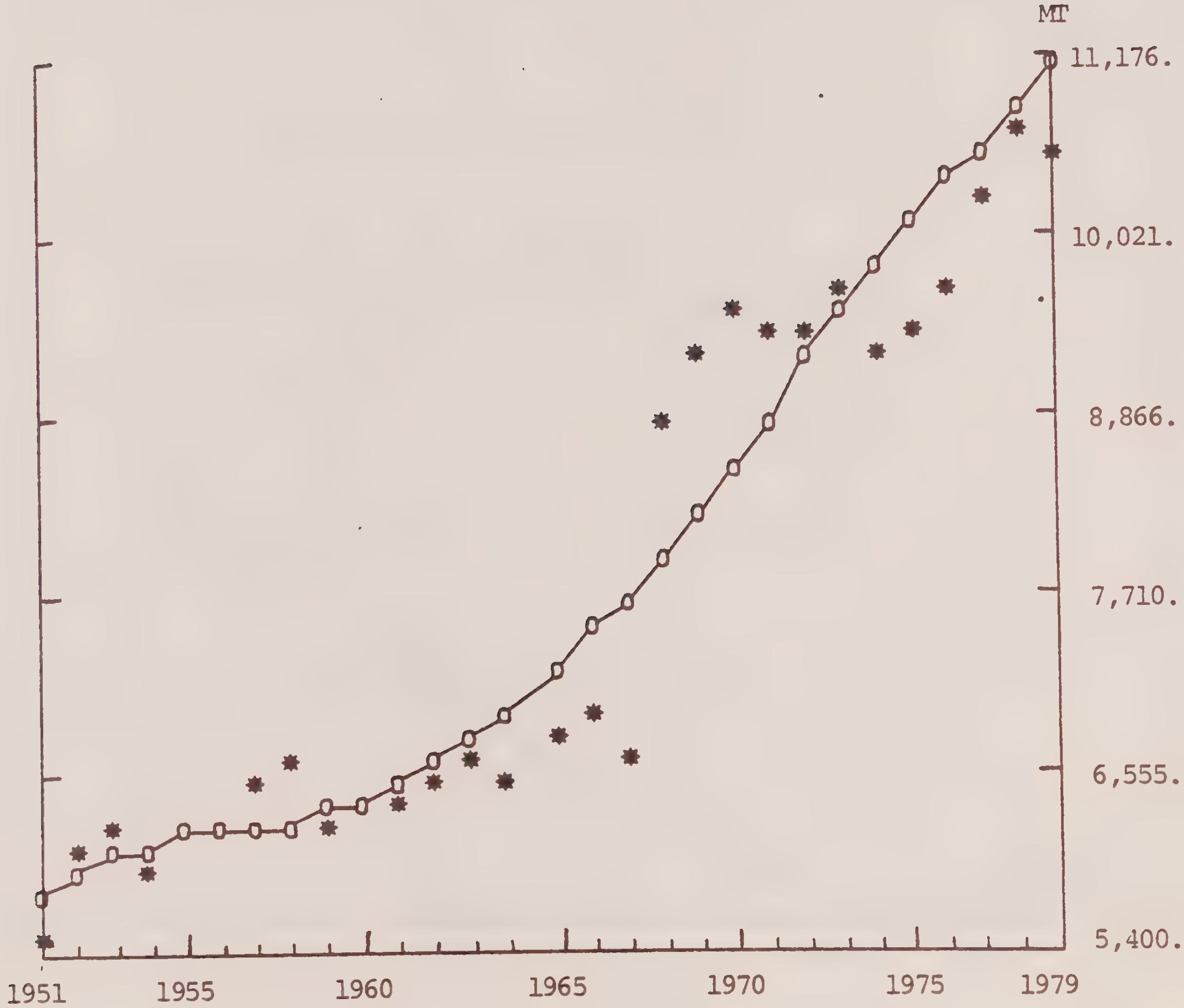
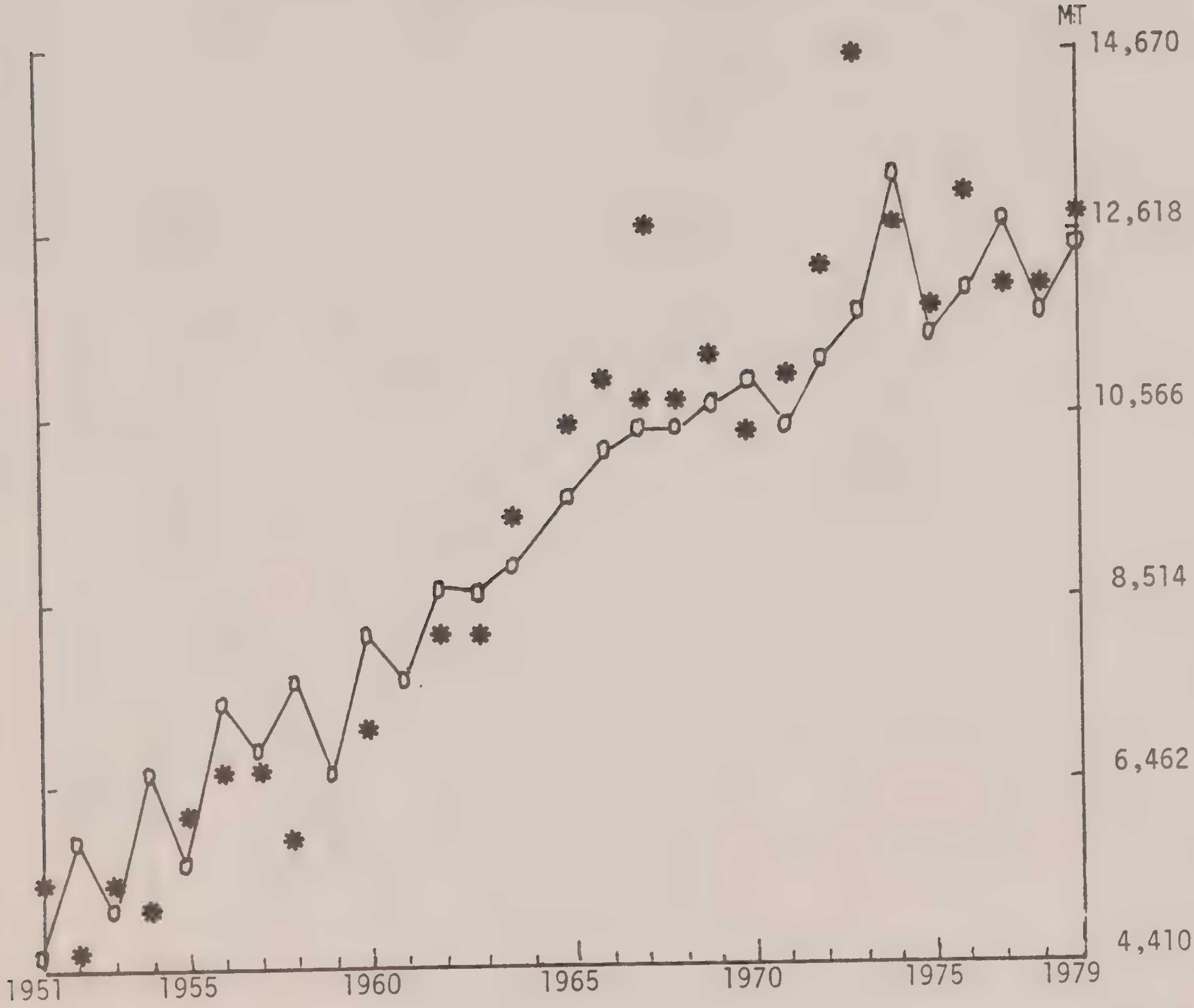


FIGURE 3

SIMULATED AND ACTUAL WORLD SILVER CONSUMPTION*)

FOR THE YEARS 1951 to 1979



*) excluding coinage.

FIGURE 4

SIMULATED AND ACTUAL GOLD PRICES IN CONSTANT 1979 U.S. DOLLARS PER OUNCE FOR THE YEARS 1951 TO 1979

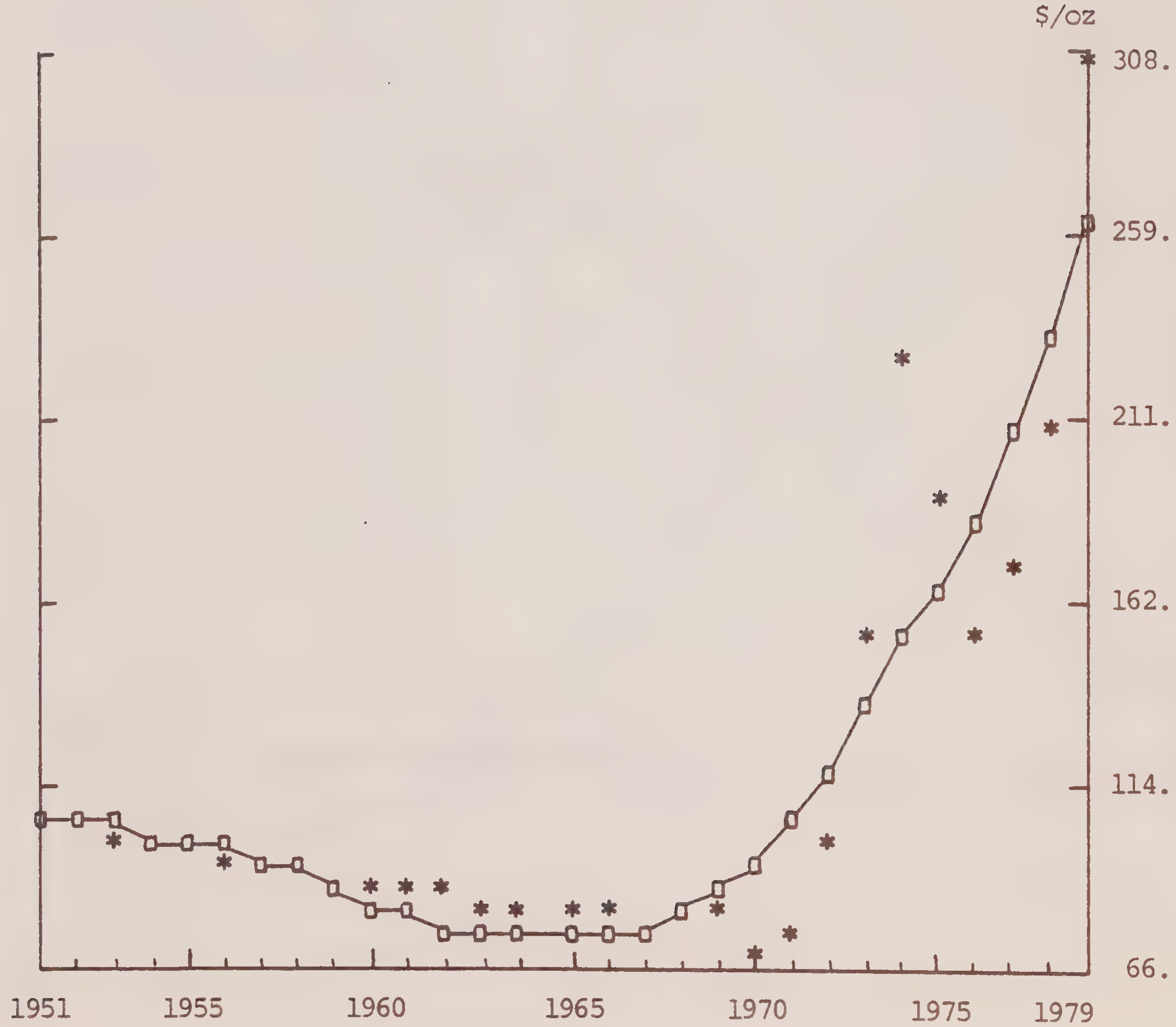


FIGURE 5

SIMULATED AND ACTUAL WORLD GOLD SUPPLY FOR THE YEARS 1951 TO 1979

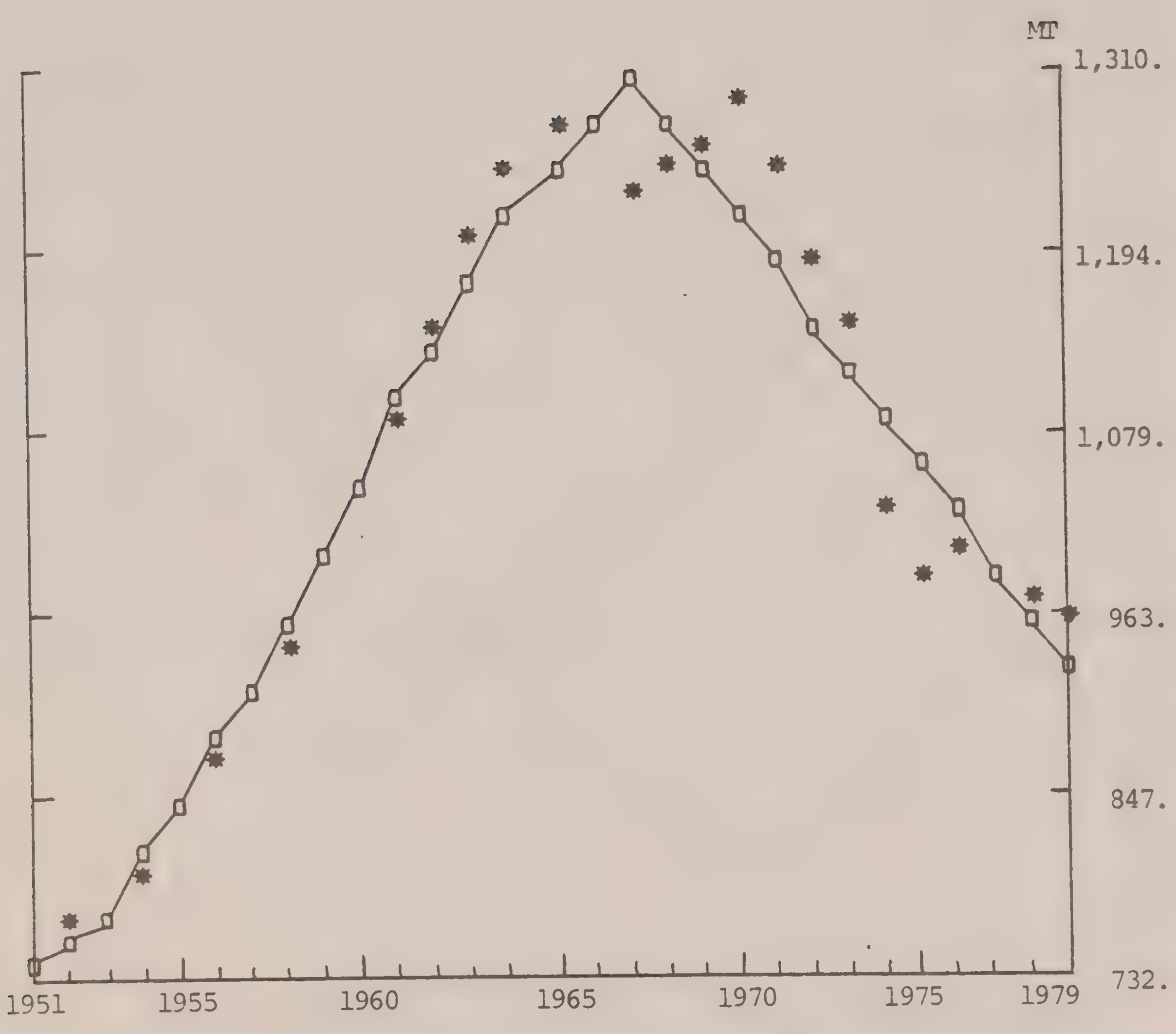


FIGURE 6

SIMULATED AND ACTUAL COPPER PRICES IN CONSTANT 1979 U.S. CENTS PER POUND FOR THE YEARS 1951 TO 1979

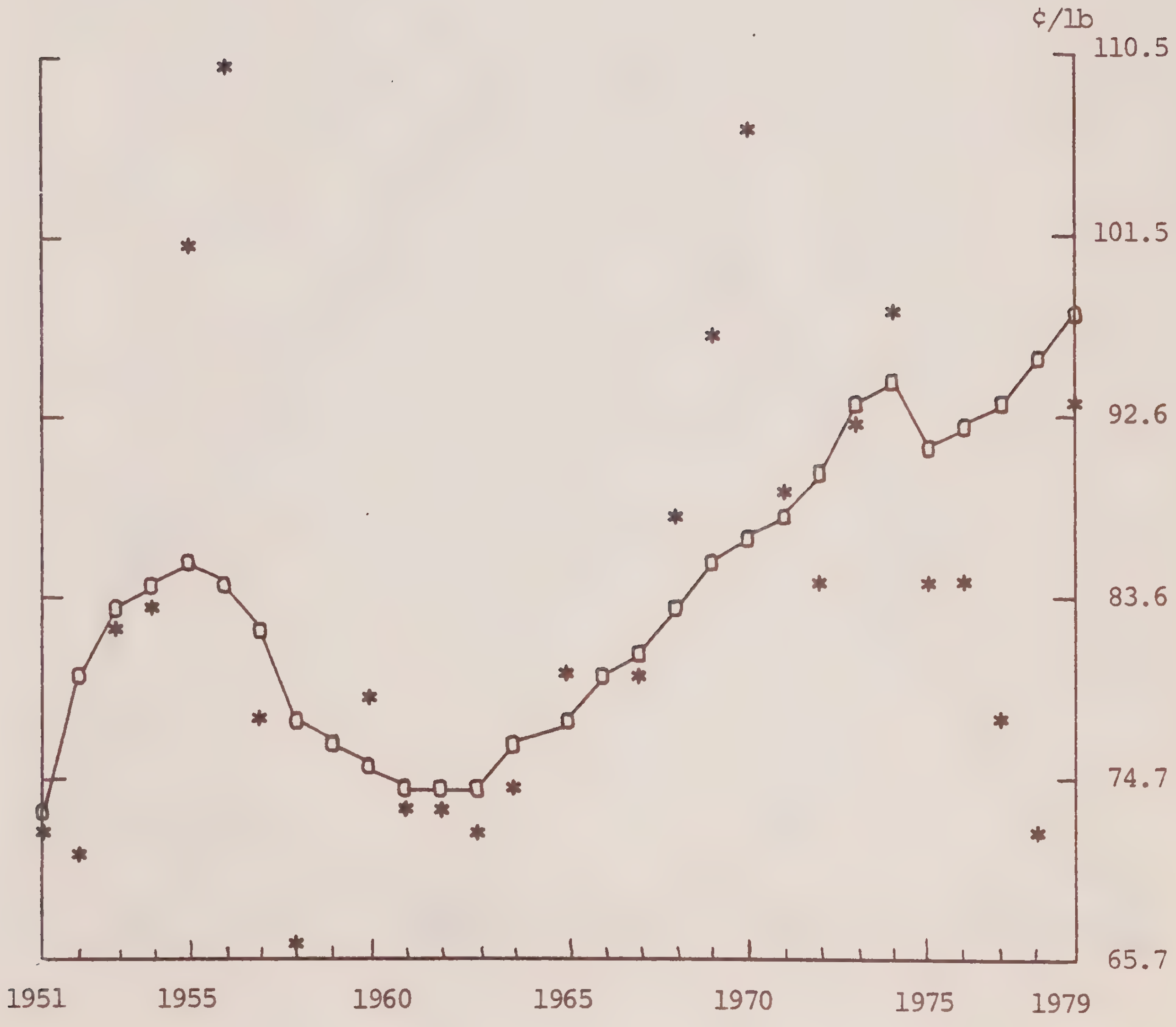


FIGURE 7

SIMULATED AND ACTUAL WORLD COPPER SUPPLY FOR THE YEARS 1951 TO 1979

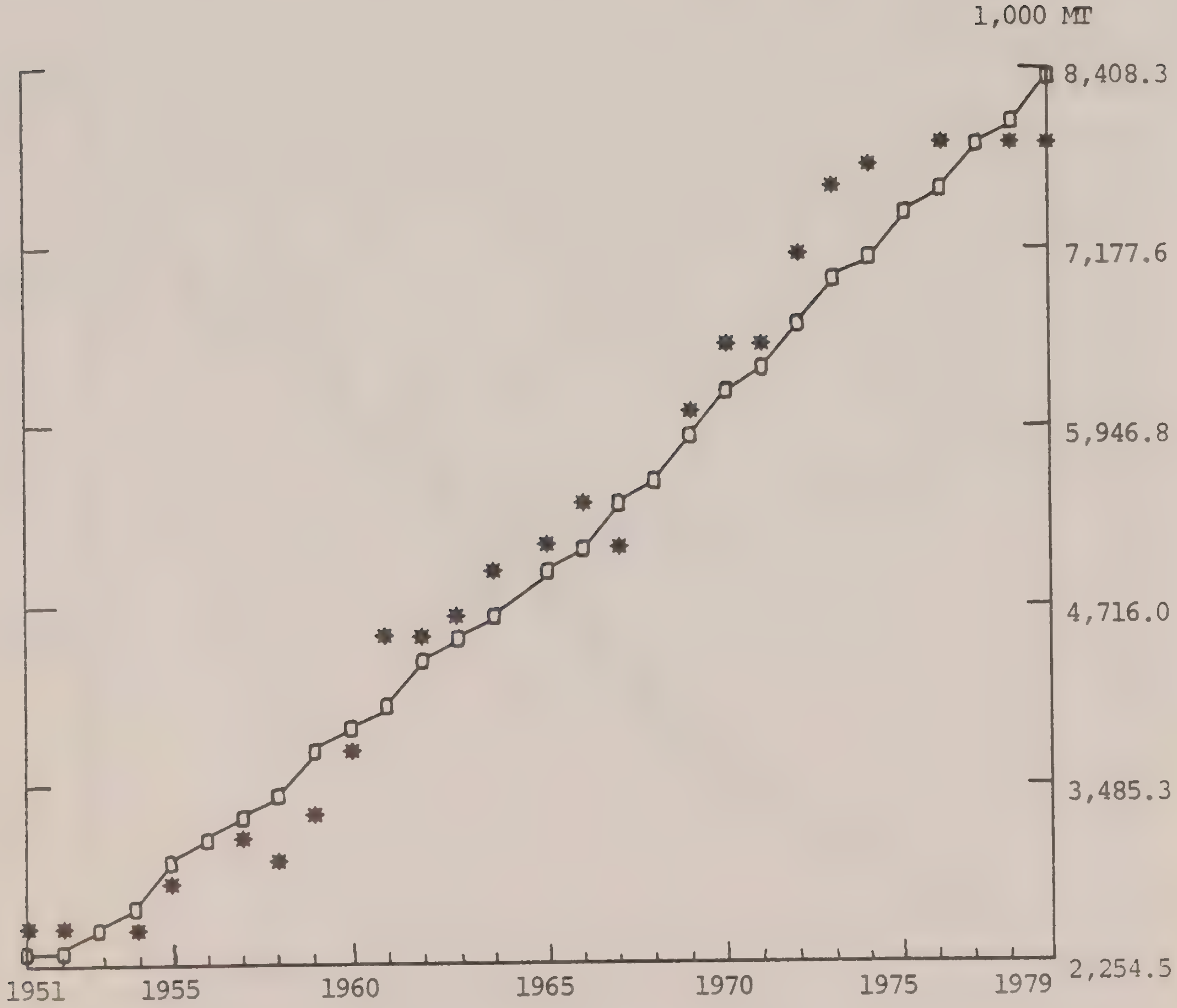


FIGURE 8

SIMULATED AND ACTUAL WORLD COPPER CONSUMPTION FOR THE YEARS 1951 TO 1979

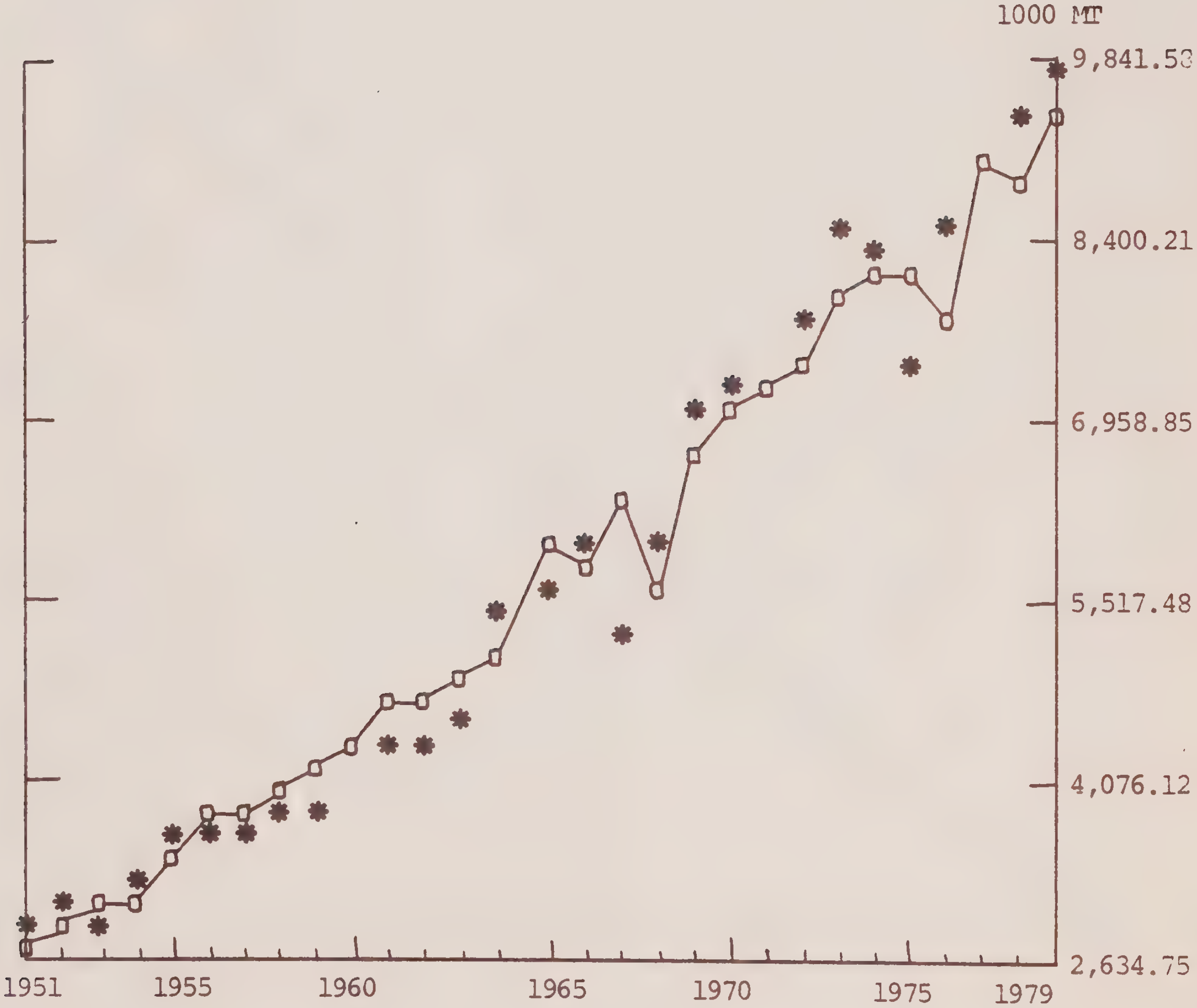


FIGURE 9

SIMULATED AND ACTUAL IRON ORE PRICES IN CONSTANT 1979 U.S. DOLLARS PER LONG TON FOR THE YEARS 1951 TO 1979

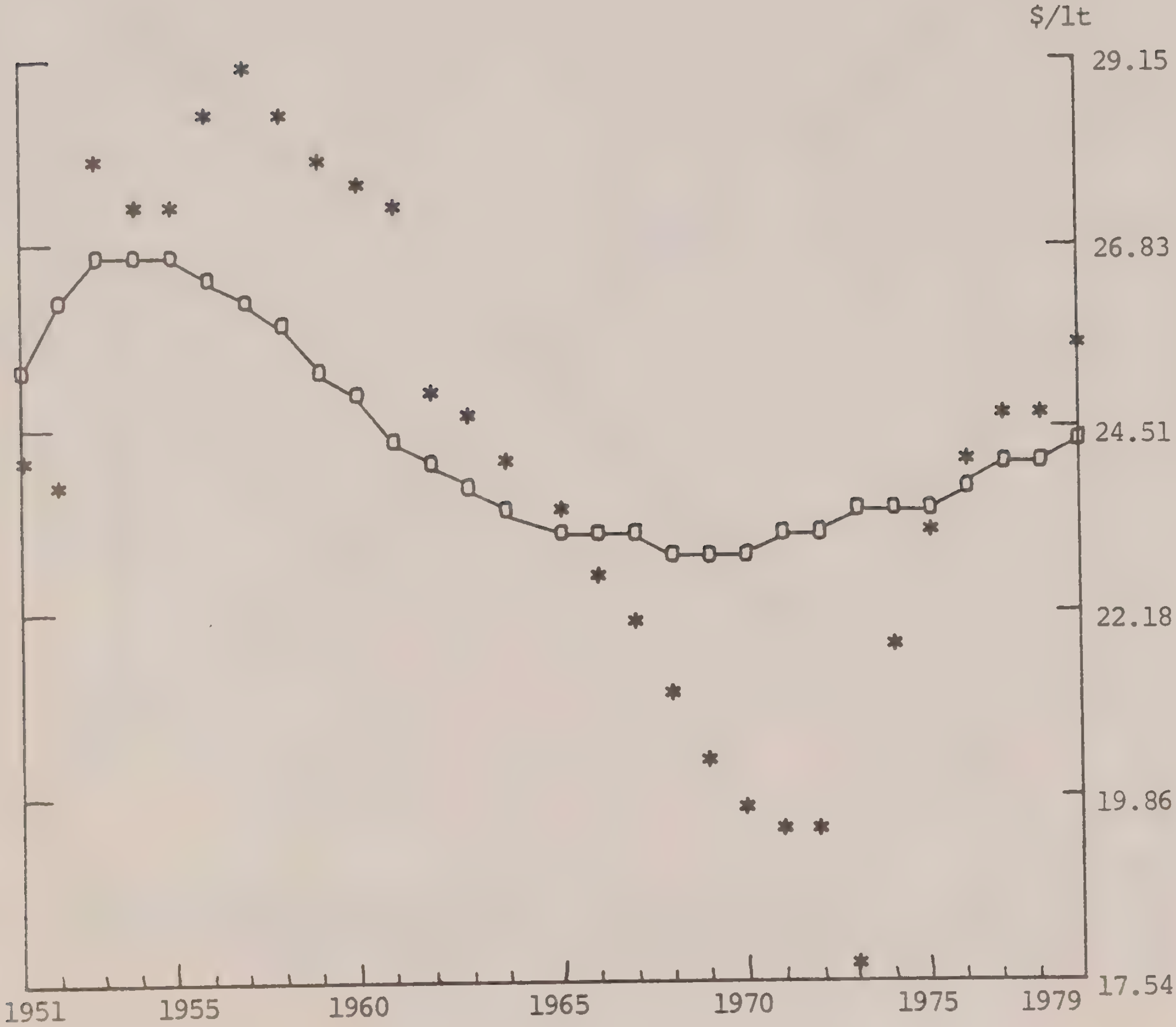


FIGURE 10

SIMULATED AND ACTUAL WORLD IRON ORE SUPPLY FOR THE YEARS 1951 to 1979

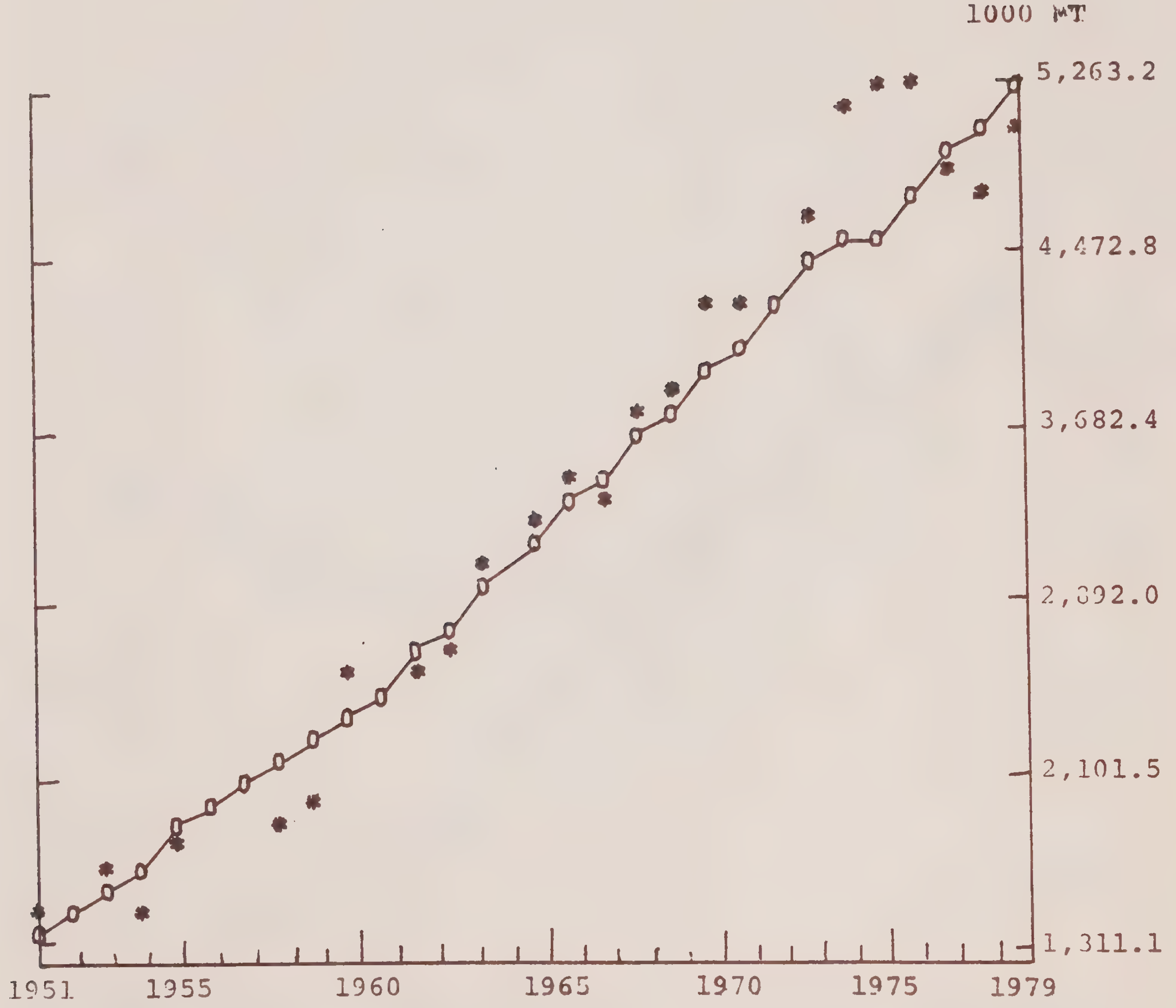


FIGURE 11

SIMULATED AND ACTUAL WORLD CRUDE STEEL CONSUMPTION

FOR THE YEARS 1951 to 1979

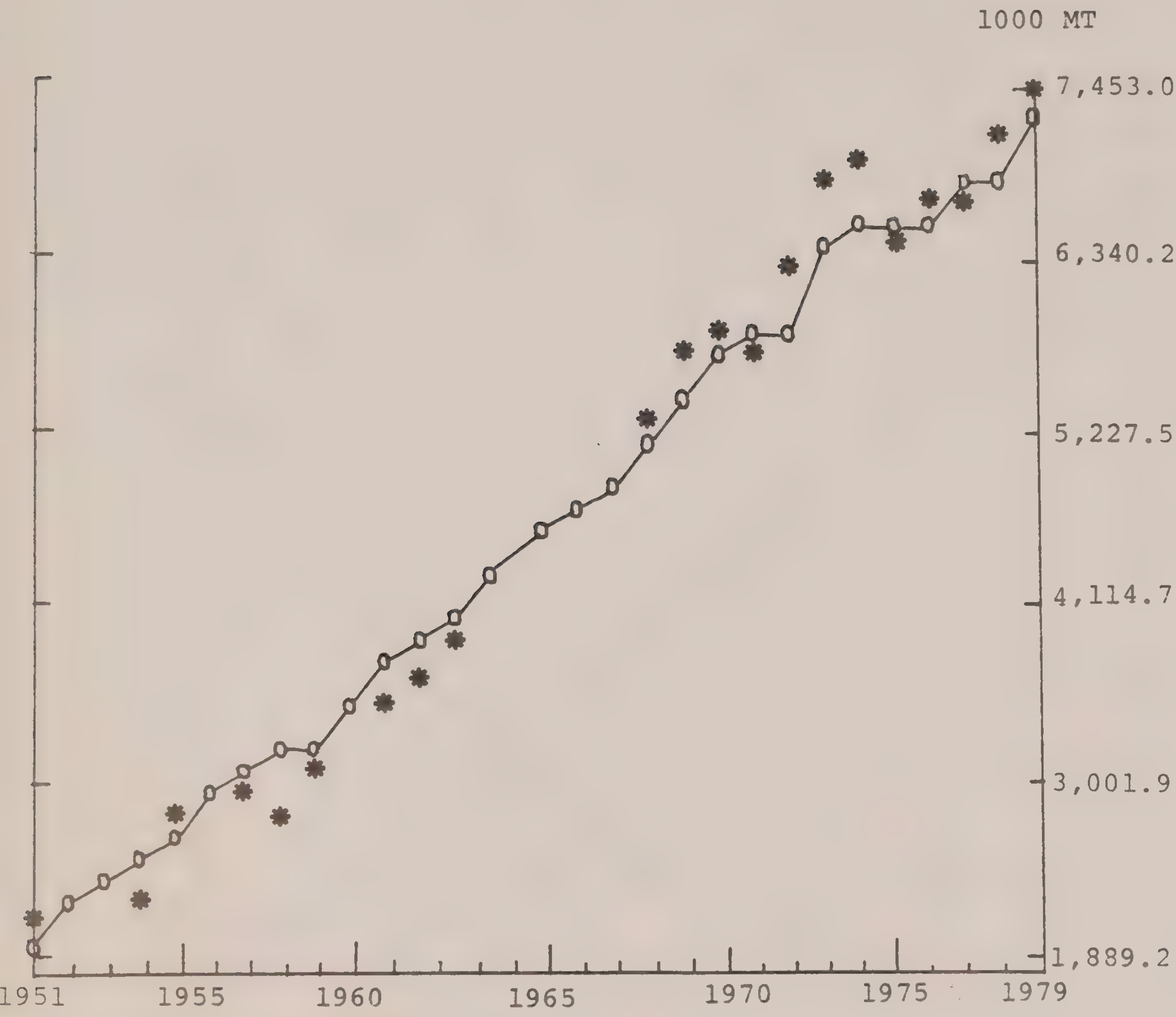


FIGURE 12

SIMULATED AND ACTUAL MOLYBDENUM PRICES IN CONSTANT 1979 U.S. DOLLARS PER POUND FOR THE YEARS 1951 TO 1979

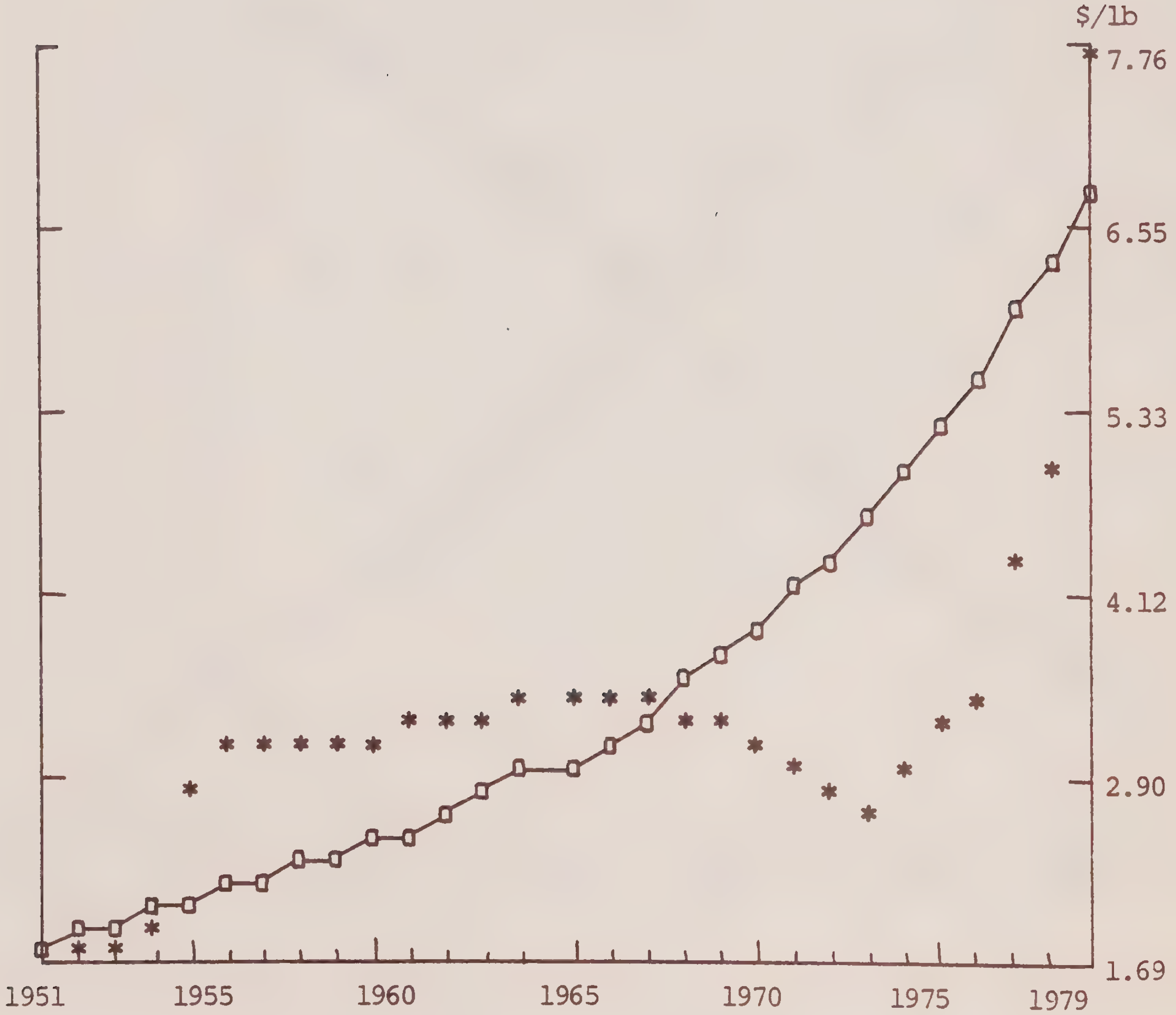


FIGURE 13

SIMULATED AND ACTUAL WORLD MOLYBDENUM SUPPLY FOR THE YEARS 1951 TO 1979

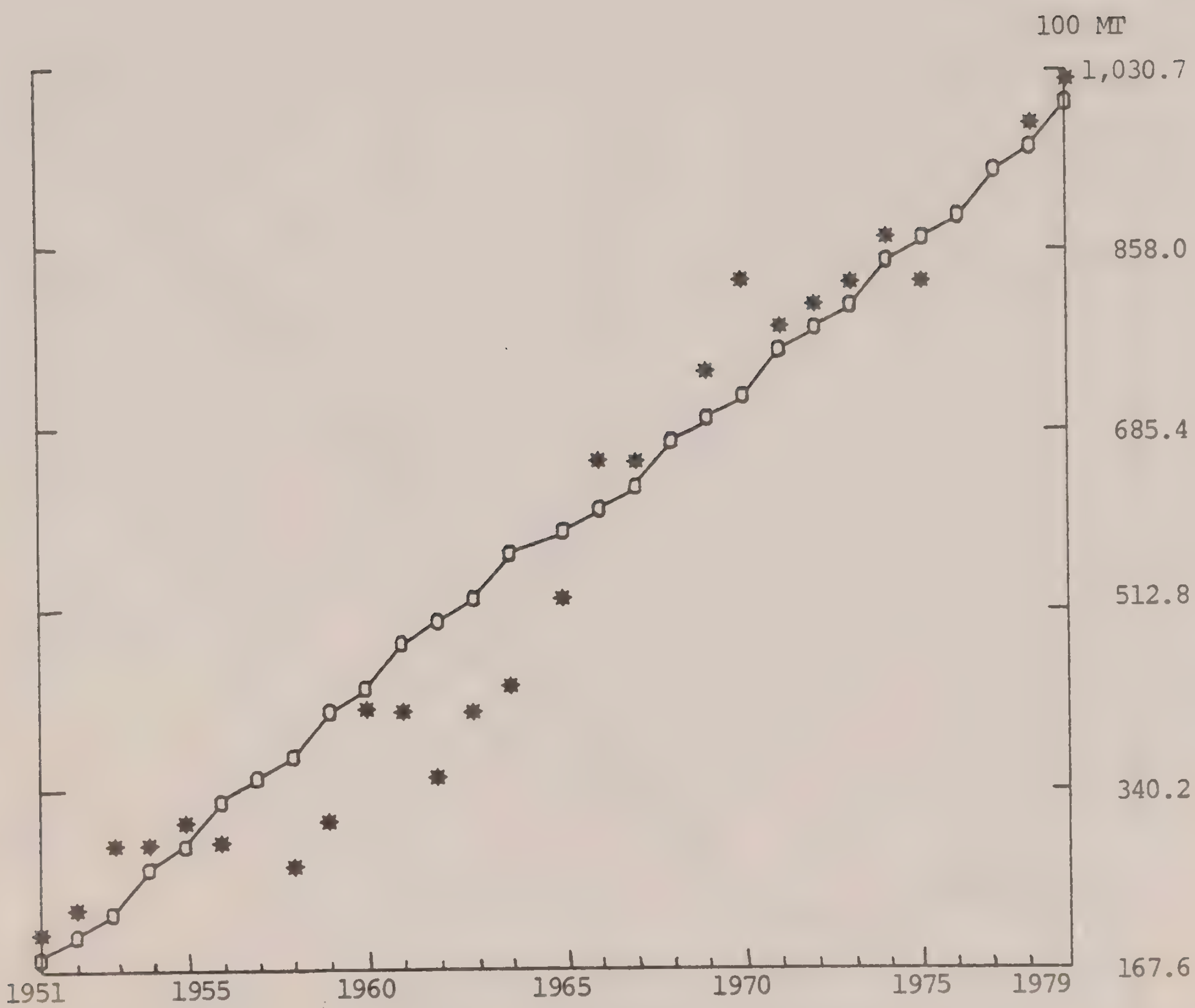


FIGURE 14

SIMULATED AND ACTUAL NICKEL PRICES IN CONSTANT 1979 U.S. CENTS PER POUND FOR THE YEARS 1951 TO 1979

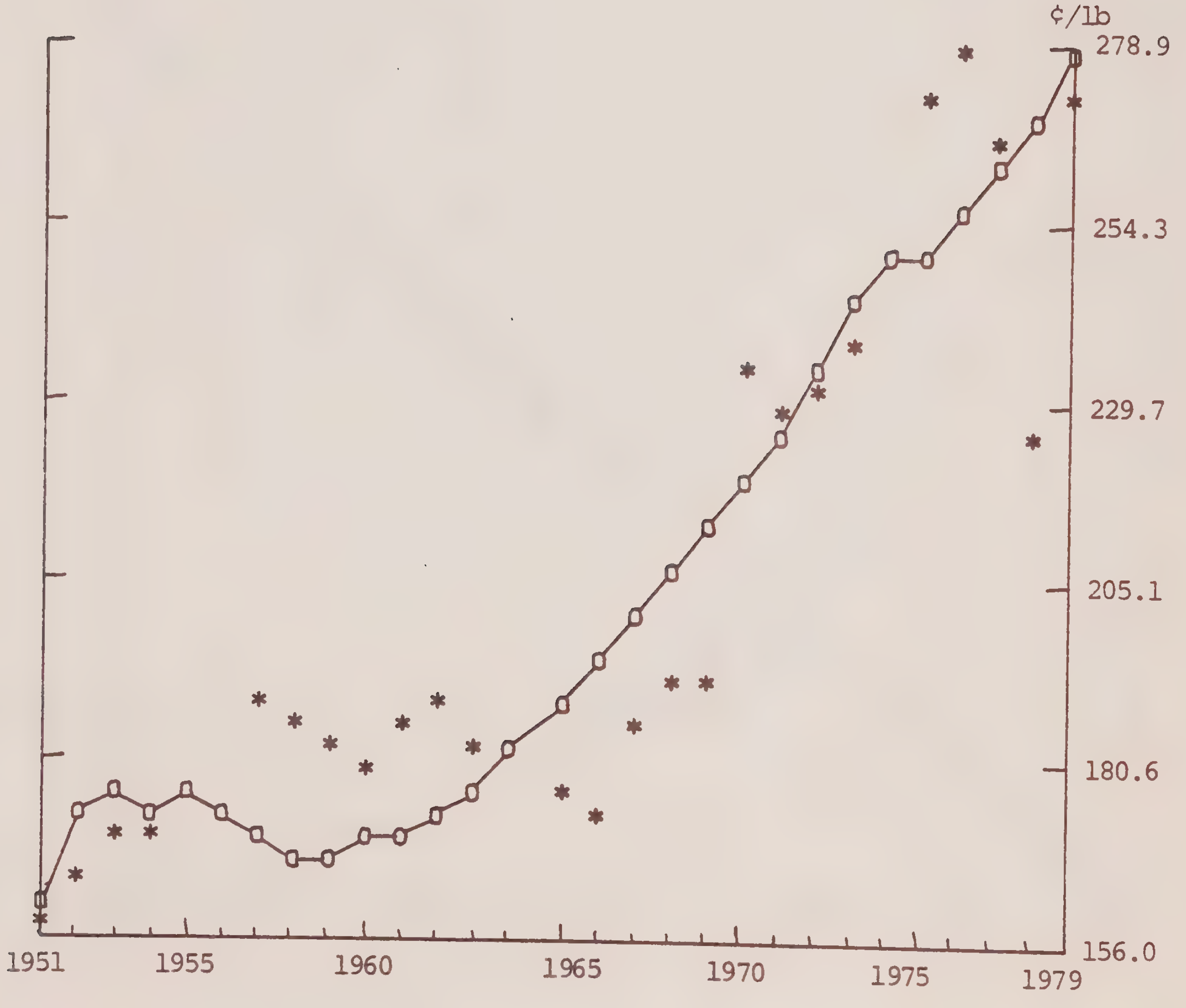


FIGURE 15

SIMULATED AND ACTUAL WORLD NICKEL SUPPLY FOR THE YEARS 1951 TO 1979

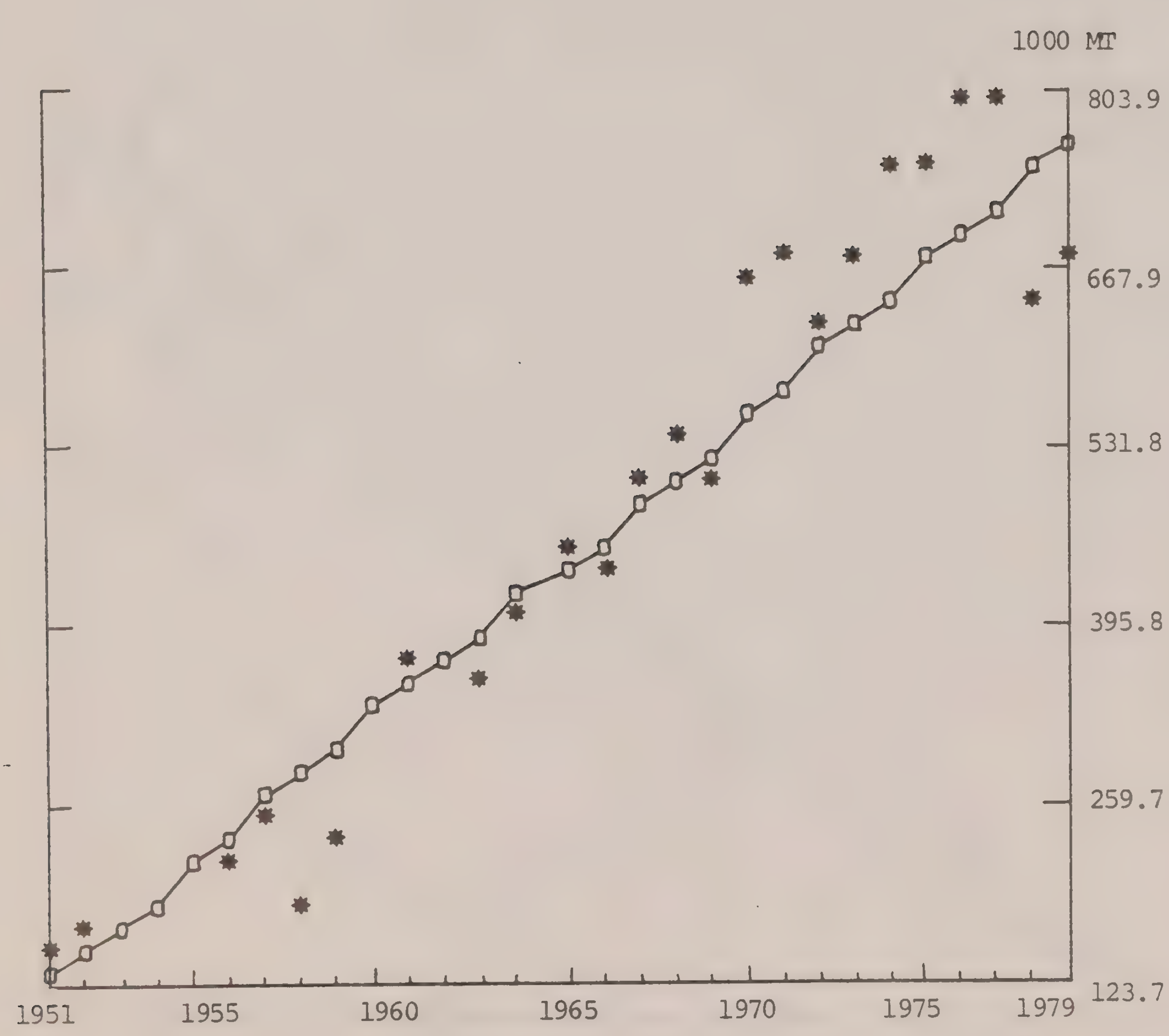


FIGURE 16

SIMULATED AND ACTUAL WORLD NICKEL CONSUMPTION

FOR THE YEARS 1951 TO 1979

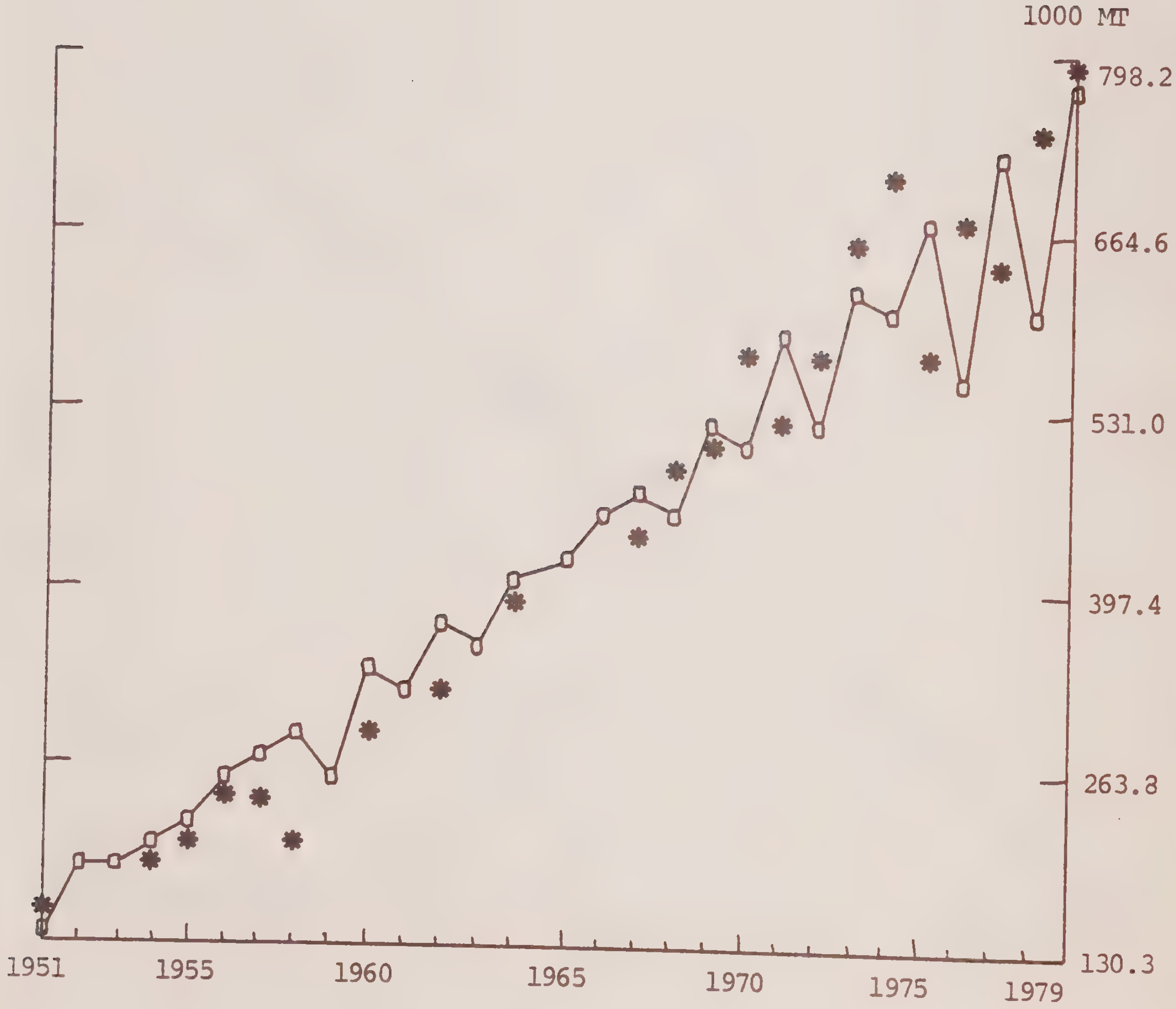


FIGURE 17

SIMULATED AND ACTUAL LEAD PRICES IN CONSTANT 1979 U.S. CENTS PER POUND FOR THE YEARS 1951 TO 1979

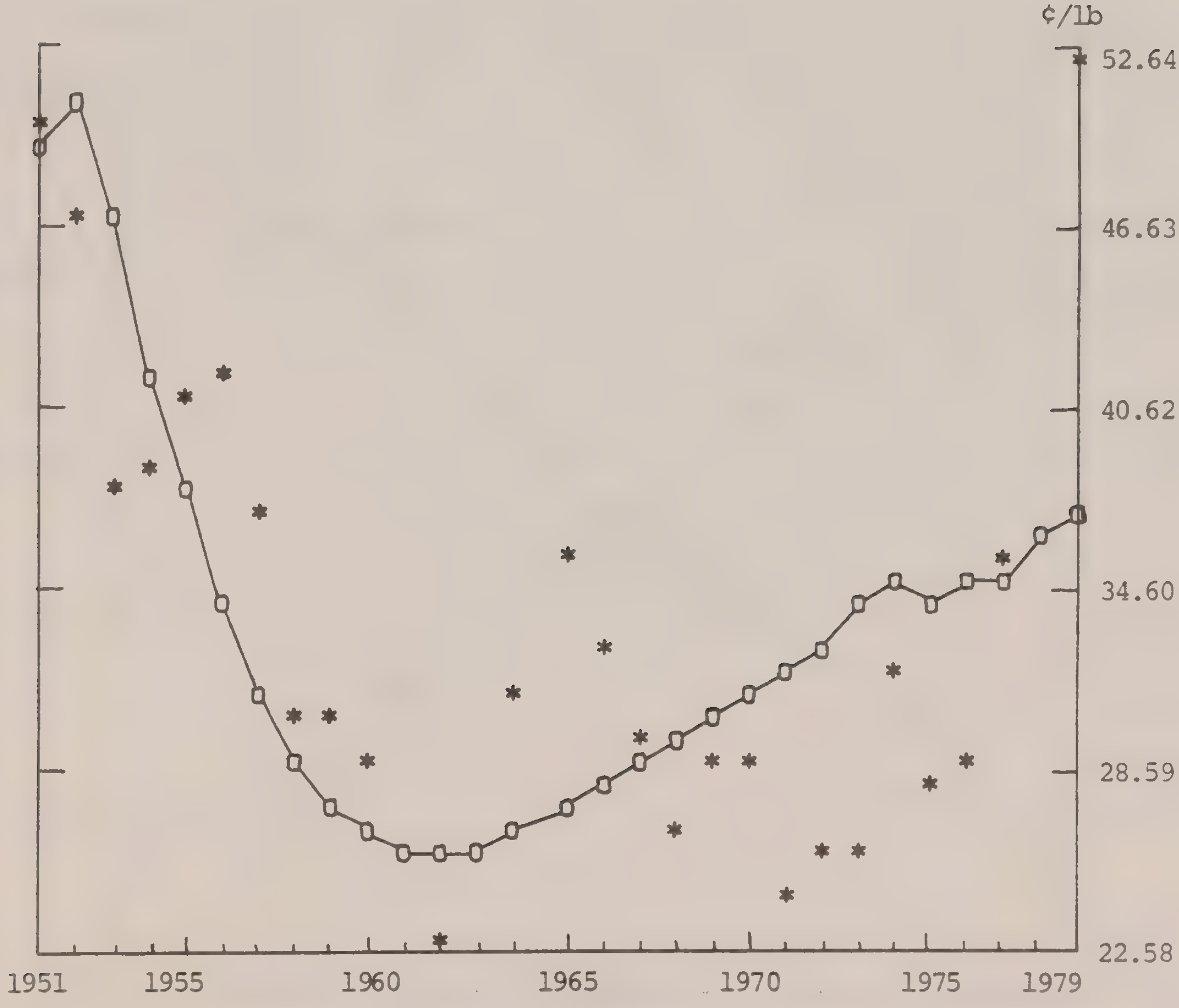


FIGURE 18

SIMULATED AND ACTUAL WORLD LEAD SUPPLY FOR THE YEARS 1951 TO 1979

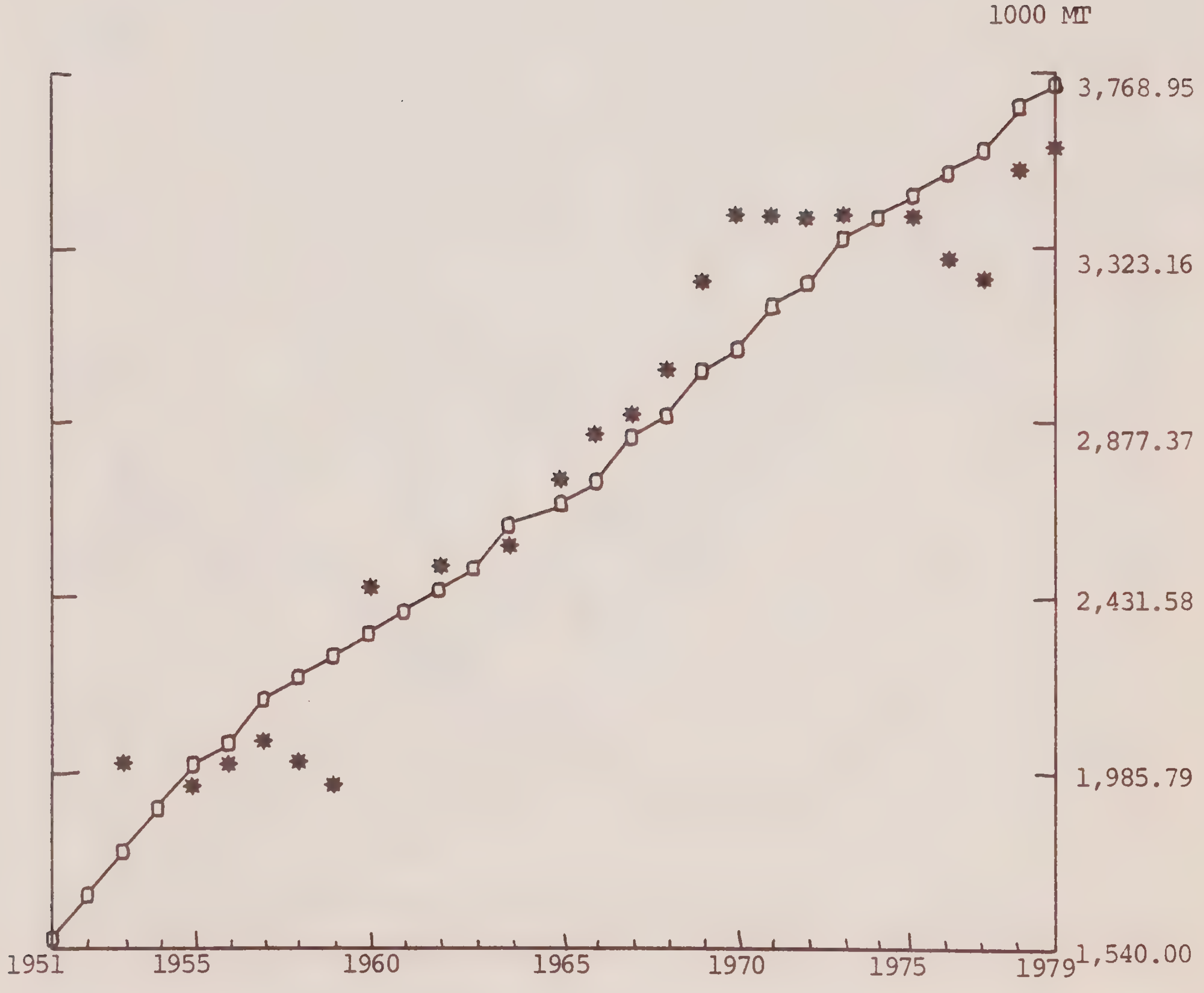


FIGURE 19

SIMULATED AND ACTUAL WORLD CONSUMPTION OF PRIMARY LEAD

FOR THE YEARS 1951 TO 1979

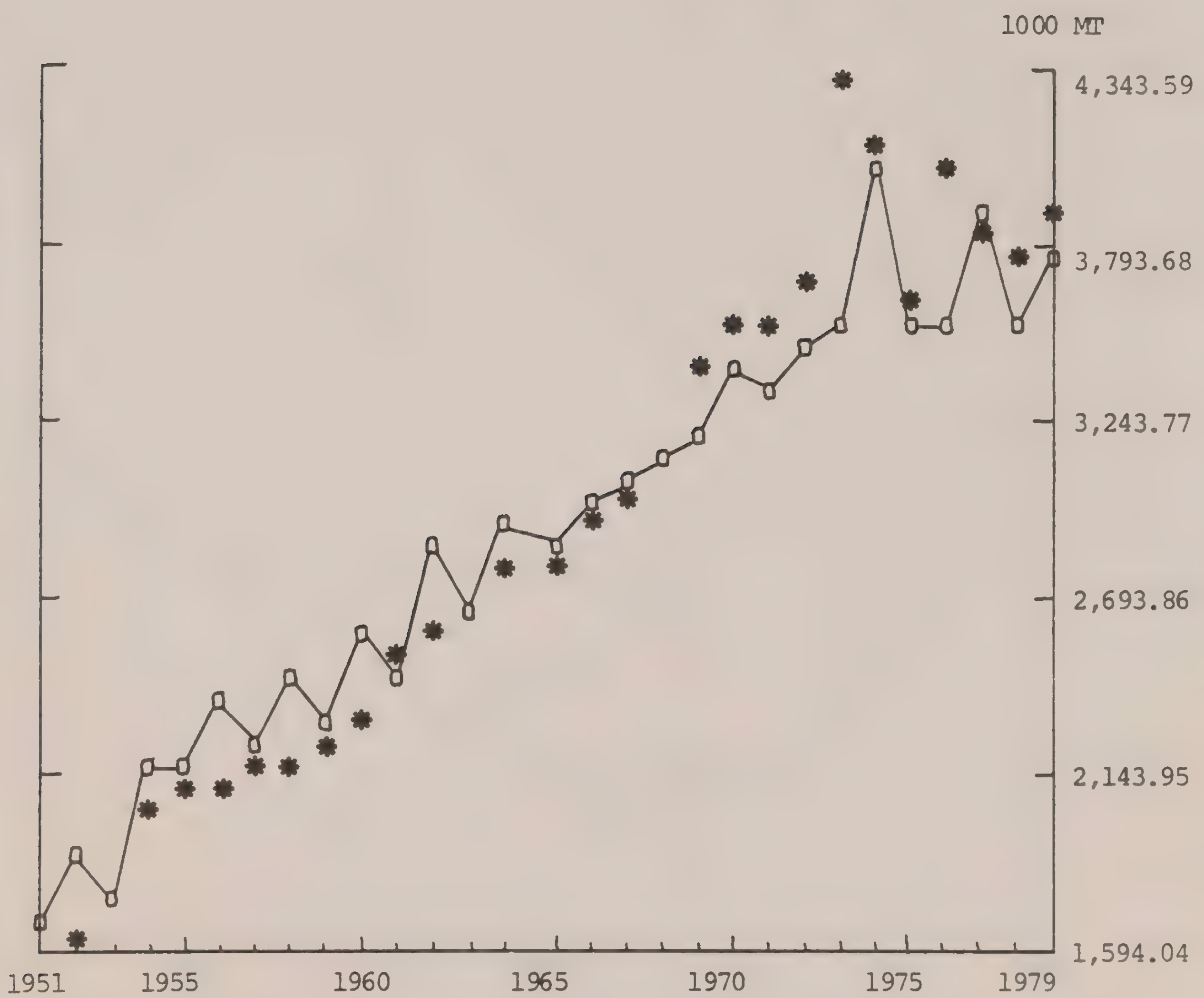


FIGURE 20

SIMULATED AND ACTUAL PLATINUM PRICES IN CONSTANT 1979 U.S. DOLLARS PER OUNCE FOR THE YEARS 1951 TO 1979

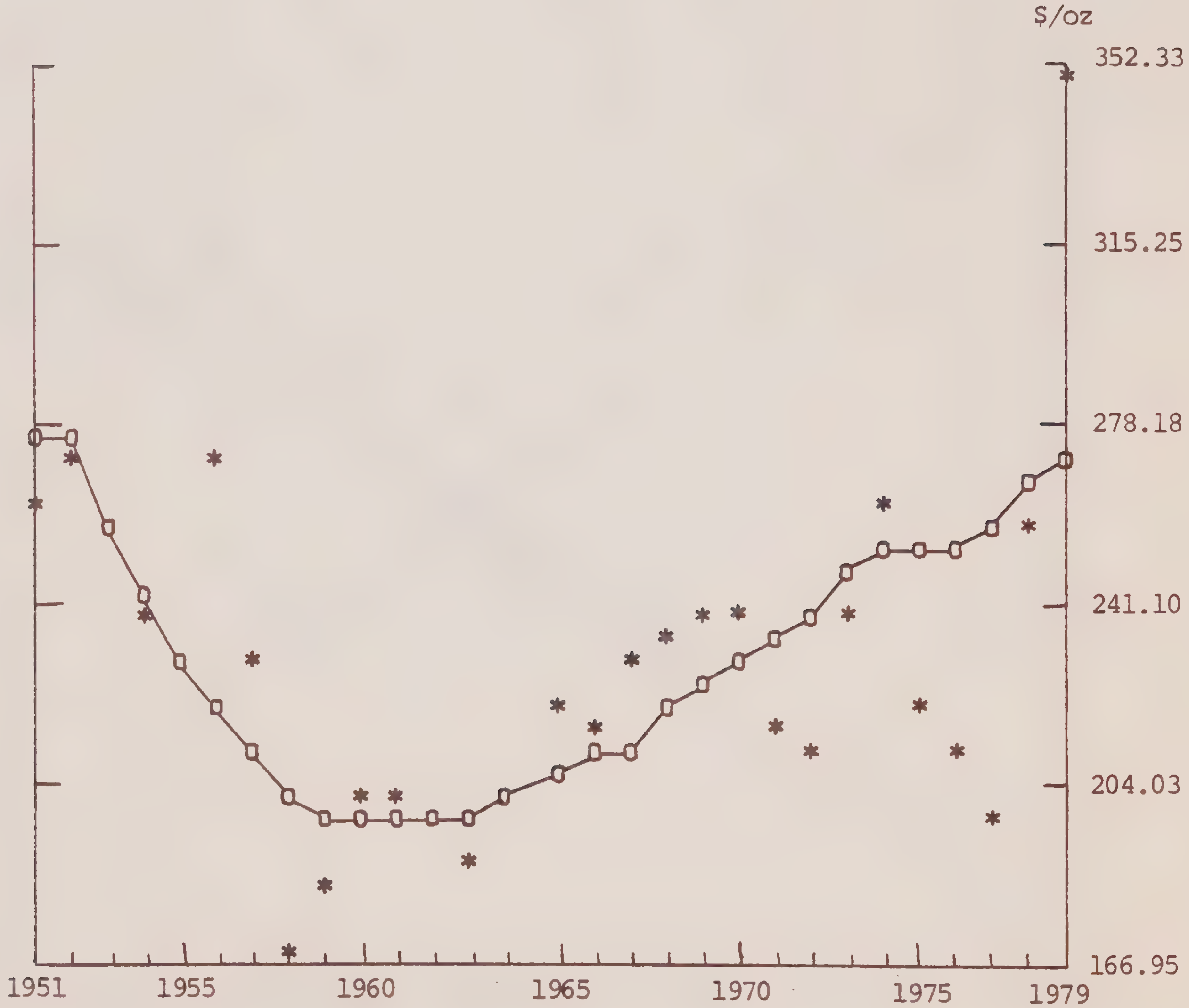


FIGURE 21

SIMULATED AND ACTUAL WORLD PLATINUM SUPPLY FOR THE YEARS 1951 TO 1979

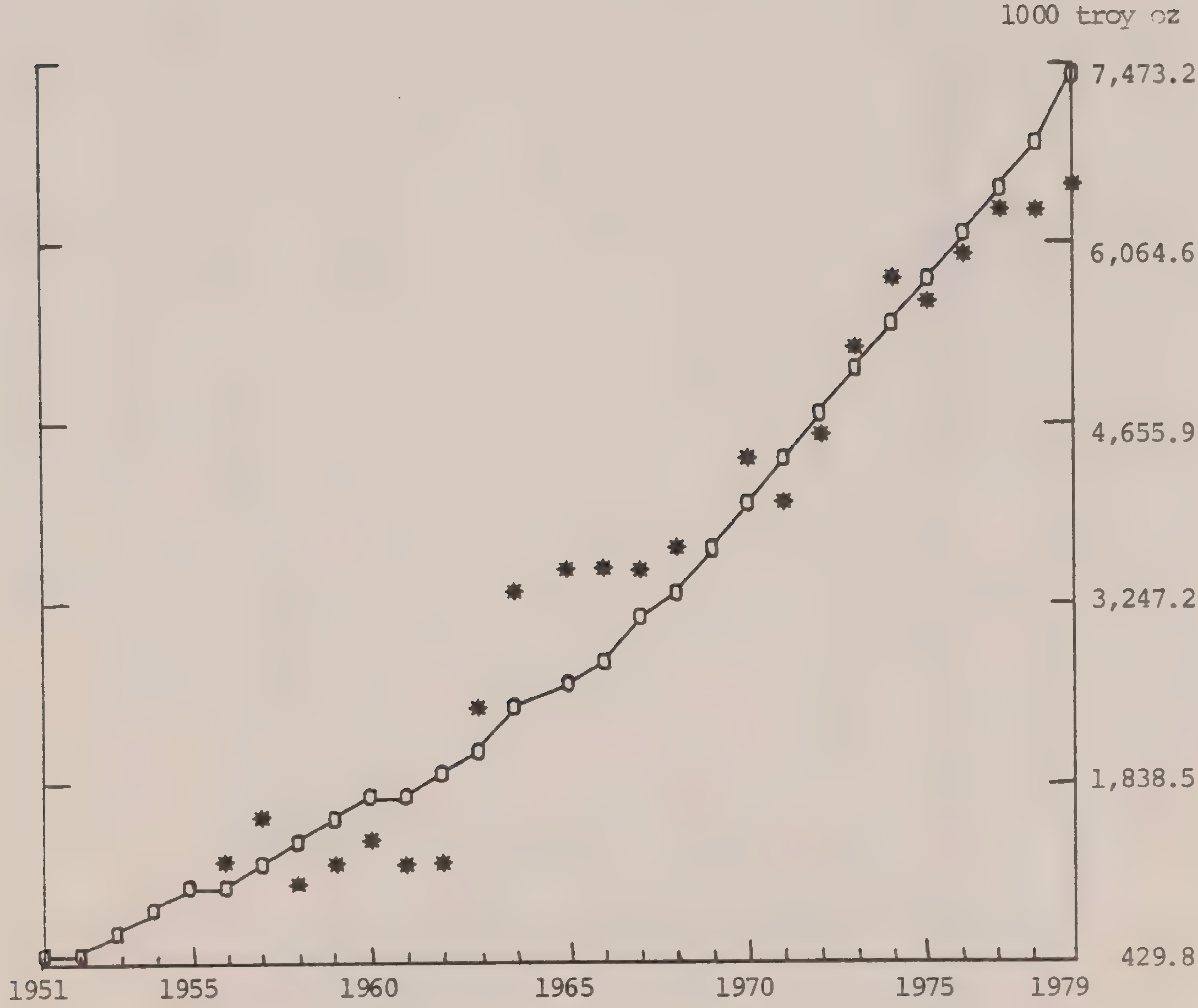


FIGURE 22

SIMULATED AND ACTUAL URANIUM NOMINAL PRICES IN U.S. DOLLARS PER POUND FOR THE YEARS 1957 TO 1979

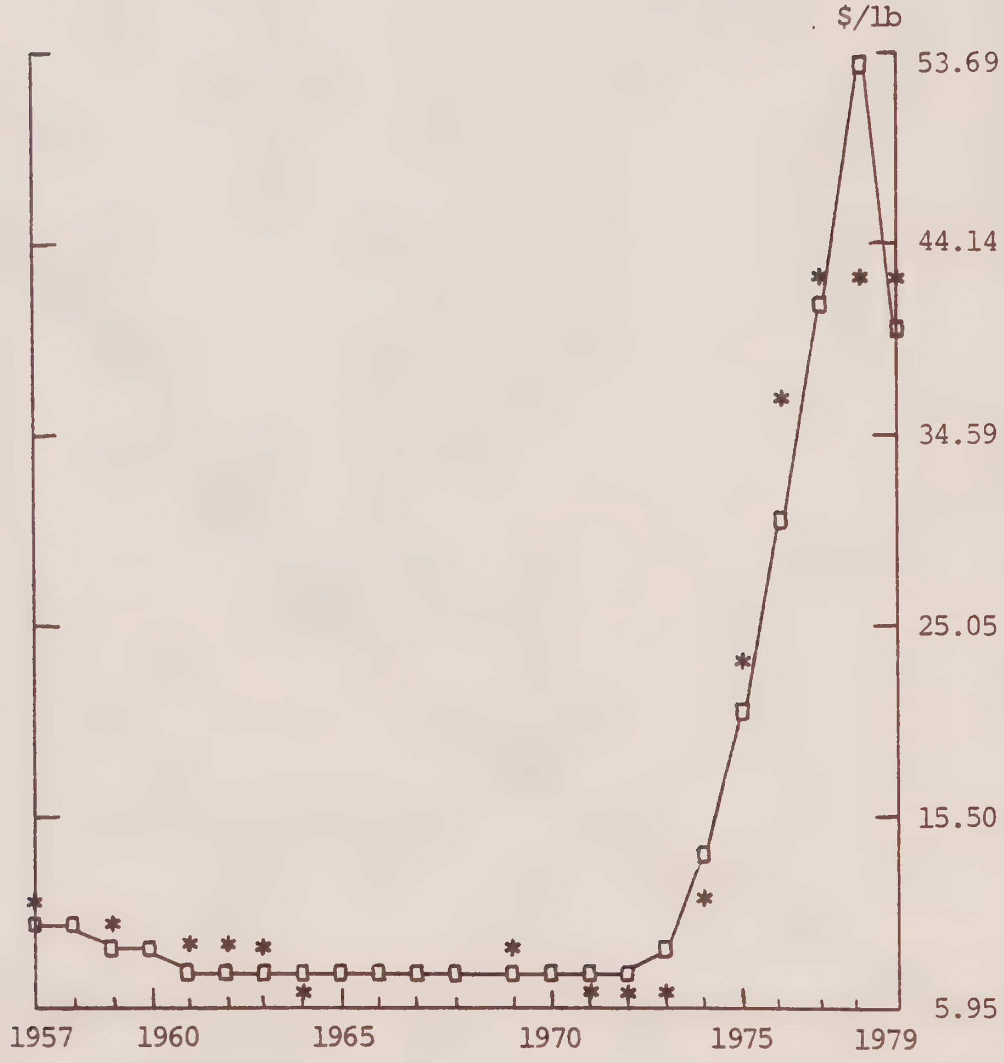


FIGURE 23

SIMULATED AND ACTUAL WORLD URANIUM SUPPLY FOR THE YEARS 1957 TO 1979

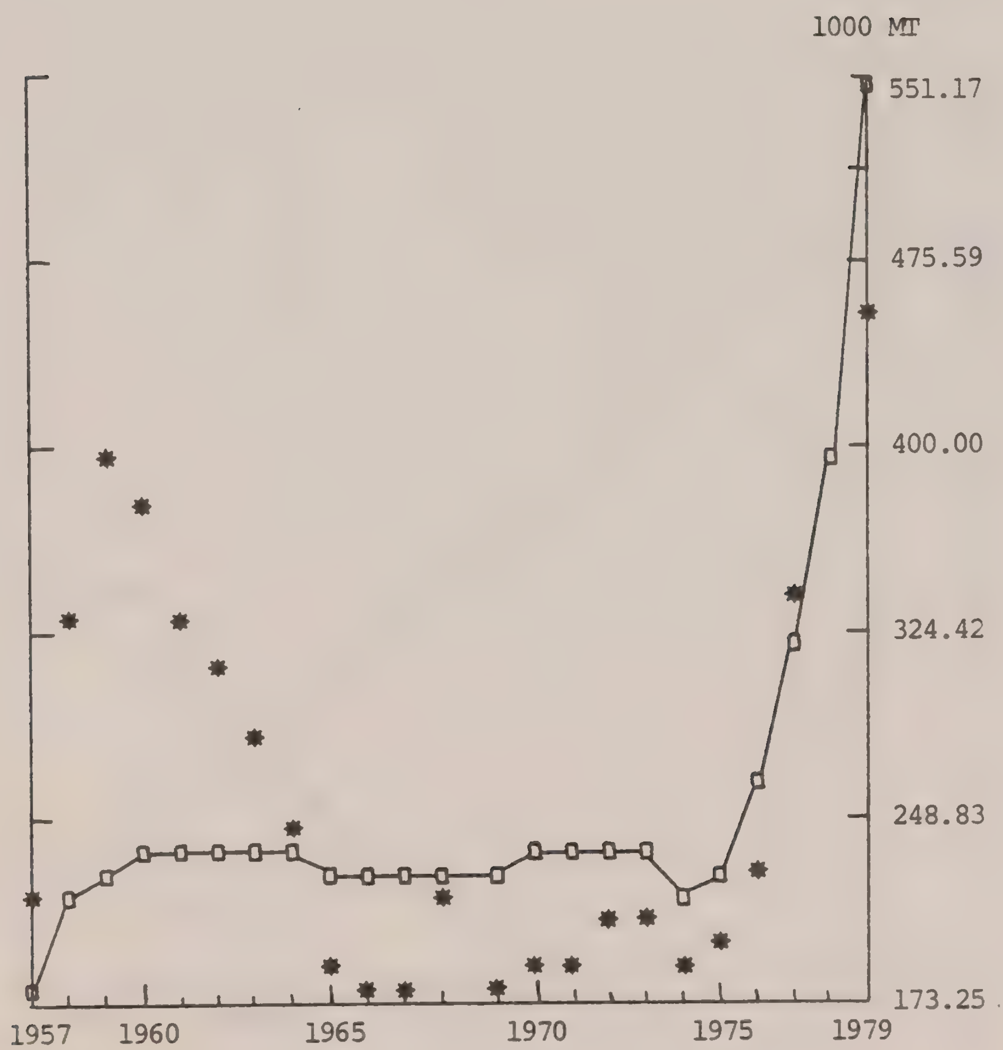


FIGURE 24

SIMULATED AND ACTUAL ZINC PRICES IN CONSTANT 1979 U.S. CENTS PER POUND FOR THE YEARS 1951 TO 1979

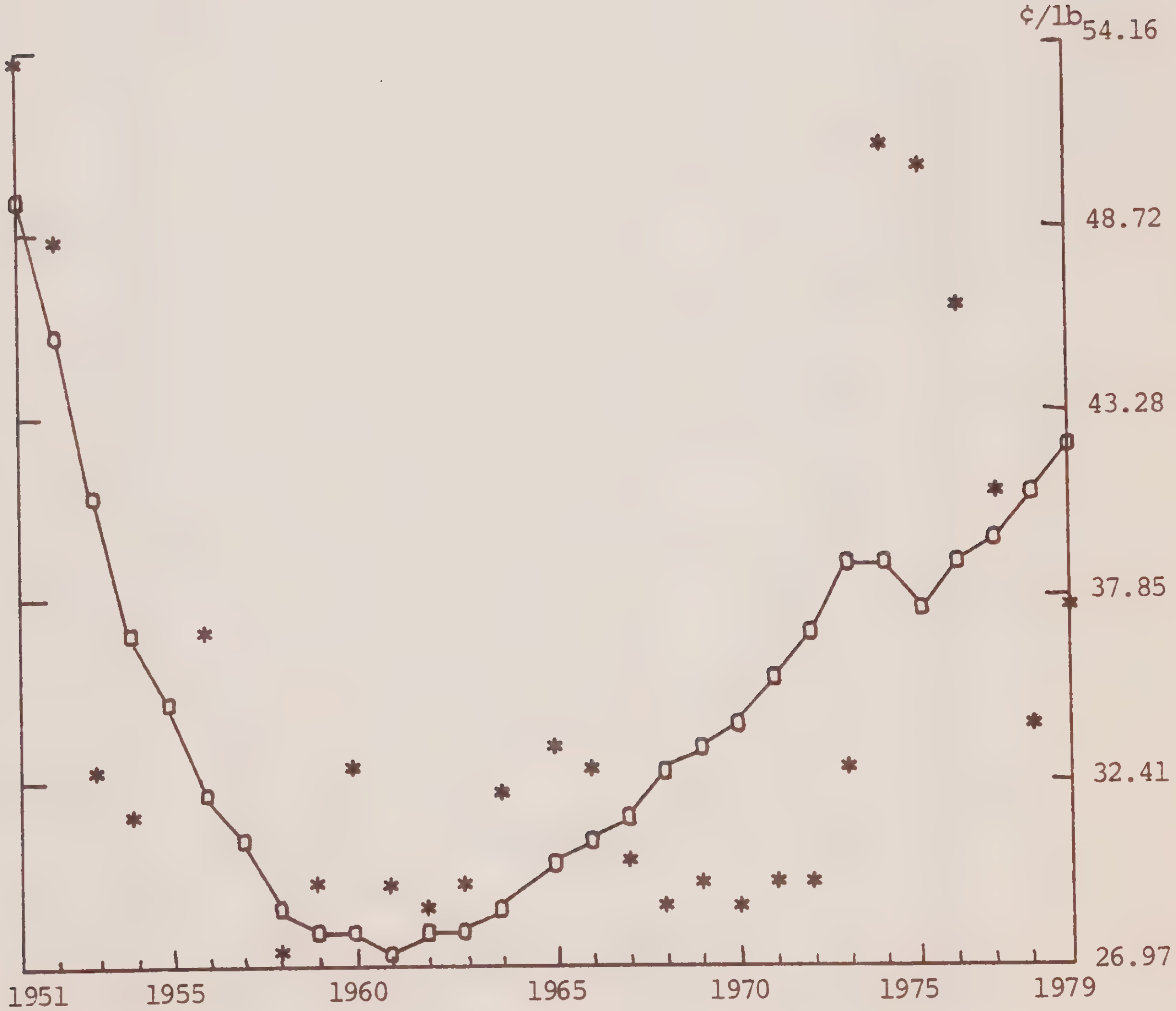


FIGURE 25

SIMULATED AND ACTUAL WORLD ZINC SUPPLY FOR THE YEARS 1951 TO 1979

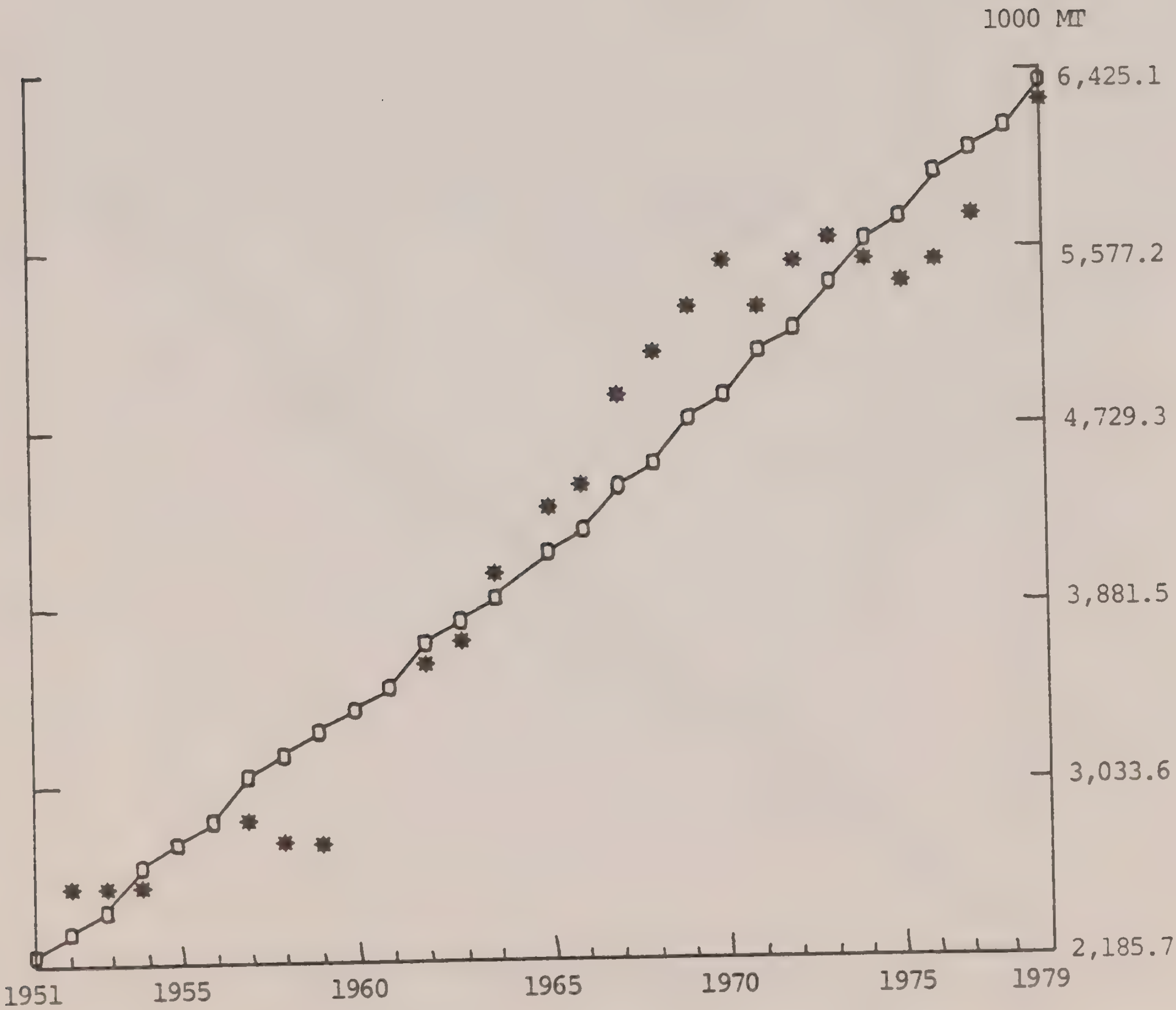
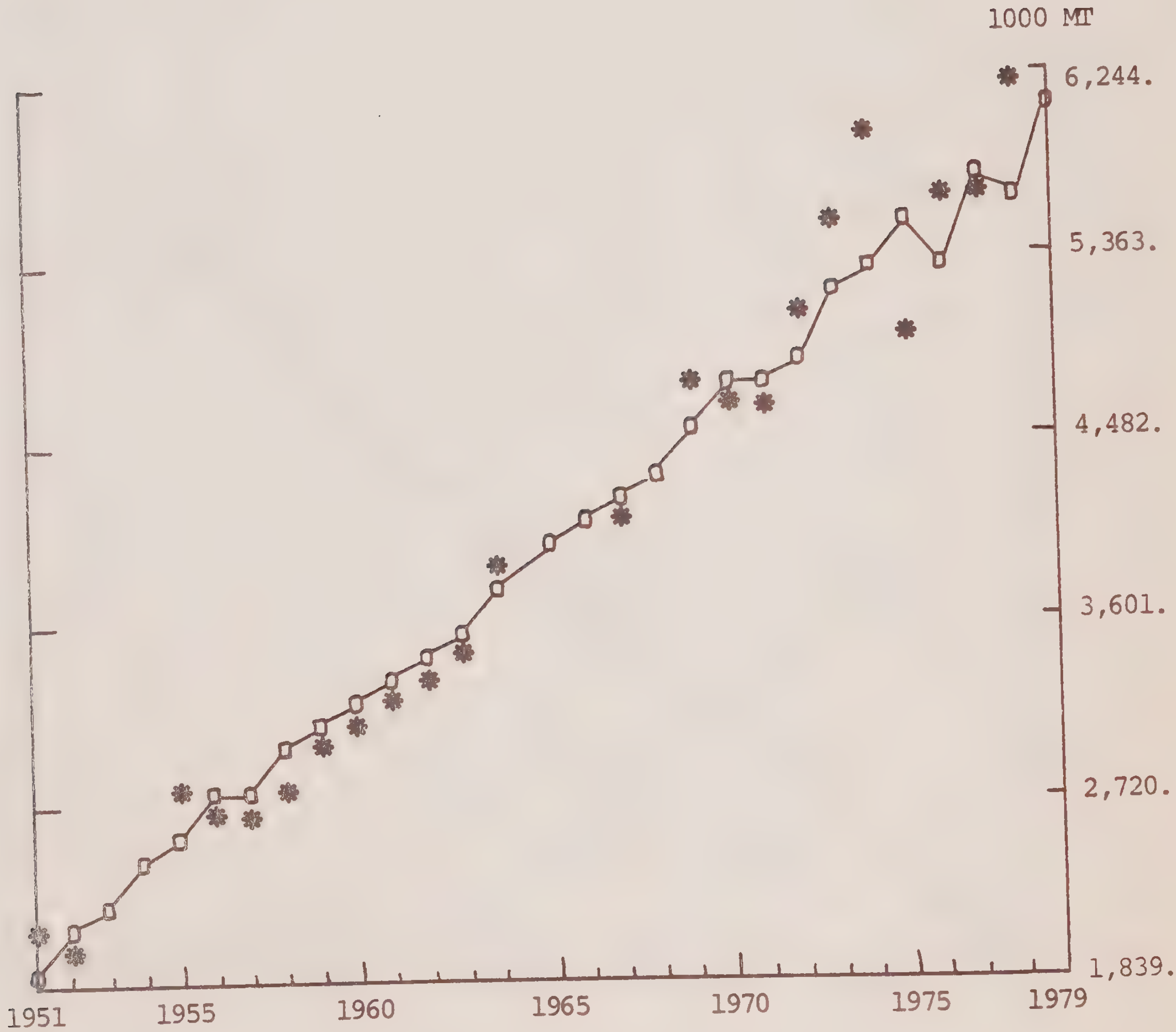


FIGURE 26

SIMULATED AND ACTUAL WORLD SLAB ZINC CONSUMPTION

FOR THE YEARS 1951 TO 1979



APPENDIX D

TECHNICAL AND BACKGROUND PAPERS

TECHNICAL AND BACKGROUND PAPERS

Technical Paper #1 -	The Undiscovered Mineral Potential of Ontario North of 50°, Dr. A. Farah and Prof. O. T. Djamgouz
Technical Paper #1 -	Political Risk Analysis, R. V. Segsworth
Technical Paper #3 -	Silver, Dr. H. Strauss and Dr. E. T. Willauer
Technical Paper #4 -	Gold, Dr. H. Strauss and Dr. E. T. Willauer
Technical Paper #5 -	Copper, Dr. H. Strauss and Dr. E. T. Willauer
Technical Paper #6 -	Iron Ore, Dr. H. Strauss and Dr. E. T. Willauer
Technical Paper #7 -	Molybdenum, Dr. H. Strauss and Dr. E. T. Willauer
Technical Paper #8 -	Nickel, Dr. H. Strauss and Dr. E. T. Willauer
Technical Paper #9 -	Lead, Dr. H. Strauss and Dr. E. T. Willauer
Technical Paper #10 -	Platinum, Dr. H. Strauss and Dr. E. T. Willauer
Technical Paper #11 -	Radioactive Fuel Minerals, Dr. H. Strauss and Dr. E. T. Willauer
Technical Paper #12 -	Zinc, Dr. H. Strauss and Dr. E. T. Willauer
Technical Paper #13 -	Sensitivity of I.R.R. to Price Changes and Determination of Economic Threshold and Desired I.R.R., Prof. O. T. Djamgouz

APPENDIX E

COMMENTS

FROM MEMBERS OF

THE ADVISORY COMMITTEE

Ministry of
Natural
Resources
Ontario

Your file:

Our file:

Room 4625
Whitney Block
Queen's Park
Toronto, Ontario
M7A 1W3

1982:11:18

Mr. G. E. Fahlgren, Commissioner,
Royal Commission on the Northern Environment,
Room 801,
Manulife Centre,
55 Bloor Street, West,
Toronto, Ontario.
M4W 1A5.

Dear Mr. Fahlgren:

I have just received the "revised" summary report by the Laurentian University Study Group. Any comments I have made in the past on the weakness of the earlier draft have obviously been totally ineffective. Neither I nor this Ministry can be in any way associated with the report which, apart from the many remaining technical weaknesses, is still so grossly misleading in its implications, as to justify labelling it irresponsible. If endorsed by me or this Ministry major embarrassment of this Government could well result.

Neither a disclaimer at the beginning of the report nor the change in the name of the committee from "Steering Committee" to "Study Advisory Committee" are sufficient to distance either myself or this Ministry adequately from the report in its entirety. I request therefore that this letter be appended to the report as a formal dissent.

This criticism is directed exclusively at the report and its authors and reflects in no way upon the Commission or the other members of the Advisory Committee, cooperation with whom throughout has been excellent.

In the review of the earlier draft it had been stated that major weaknesses in that draft were in the areas of data accuracy, of interpretation of computer results and their translation into forecasts, and in the use of geo-statistical analysis. These weaknesses were in part due to lack of contact with competent

professionals. Such contacts could have eliminated a lot of these problems, but there is no evidence that meaningful interchange of ideas took place since. We had further major concerns in the investment climate analysis of foreign countries contained in the report, as numerous passages conveyed a strong left wing bias. Lastly, summary statements of the results of geo-statistical investigations could be misinterpreted and lead to ill founded demands for policy action or fraudulent promotional activity. Furthermore, totally inadequate attention was paid to the crucial issues of Canadian investment climate.

In the course of the discussions, the Laurentian University writing team responded to the criticism, that many elements of the report lacked realism and provided a base for ill founded conclusions, essentially in the same way, whether the subject was forecasting, risk analysis,geo-statistics or the use of sources. They stated that their sources were properly documented and that the arithmetic of their calculations was correct. This was never challenged but the central point never seemed to get across that the writers of such a report have to take certain responsibilities for the way it may be used by non-academic readers and that this responsibility goes well beyond adherence to formal standards applied to students' term papers or to technical papers in academic journals.

With respect to the calculation of place values of specific mineral commodities, it was outlined in detail how the reader unfamiliar with the technical literature on geostatistics could come to the conclusion that major mineral resources, worth hundreds of billions of dollars, only wait to be developed "North of 50". The probabilities given in the report, in the context of conventional probabilities associated with the discovery and development of mineral deposits, suggest that the development of these deposits amounts to virtual certainty. It is rather obvious how this material may generate mischief, both in the private as well as in the public sector.

Other serious theoretical and practical problems pertaining to relations of specific production, consumption and price forecasts were also brought to the attention of the authors.

During the half year that passed between the discussion of the first draft and the submission of the final volume, only a very few minor cosmetic changes were made, but changes relating to the major criticisms made earlier were totally insufficient.

It is for these reasons that neither I nor the Ministry can endorse this report in any way whatever, and must in effect reject it as unprofessional, substandard, misleading and irresponsible.

G. Anders,

G. Anders, Ph.D., Dipl. Ing.
Senior Policy Advisor and Supervisor,
Metallic Minerals Section,
Ontario Ministry of Natural Resources.
Adjunct Associate Professor,
University of Toronto, (Geological Engineering).

GA:mm

cc: Ian S. Fraser, Director of Research.
Dr. T.P. Mohide,
Mr. J.E. Finlay.

Rec'd Nov. 29/82
& copied to
Jon Del Ben

Scott Consulting Services

Box 1298, Atikokan, Ontario. P0T 1C0
Telephone 807-597-6193; Summer, 807-929-3201

RECEIVED
FEB 3 1983
ROYAL COMMISSION
ON THE
NORTHERN ENVIRONMENT

January 27, 1983

Mr. Ian Fraser
Director of Research
Royal Commission on the Northern Environment
Manulife Centre, Room 801
55 Bloor Street, West
Toronto, Ontario
M4W 1A5

Dear Mr. Fraser:

Re: Report on the Future of Mineral Development on Ontario North of 50 degrees N.

Thank you for sending me a copy of the revised summary report by the Laurentian University Study Group.

The scope of the report is very ambitious. For example, it attempts to make a number of evaluations with respect to minerals in a largely uninhabitated area of 210,000 square miles. This is an area the size of France. I commend the Commission for undertaking an analysis of such a land mass.

Given the large scope of this study, I believe it safe to assume that some conclusions have to be based on meagre data and may be misleading. On balance, however, the Commission and authors were correct in taking a broad approach. They have provided a foundation for future work and a report that will have beneficial impact on society.

Yours truly,

Nat Scott.

N. S. Scott, P. Eng.

NSS/bas

Scott Consulting Services

Box 1298 Atikokan, Ontario P0T 1C0
Telephone 807-597-[illegible]; Summer, 807-[illegible]

January [illegible], 1989

Mr. Ian Stewart
Director of Research
Royal Commission on the Northern Environment
[illegible] Centre, Suite 801
[illegible] Bloor Street, East
Toronto, Ontario
[illegible]

Dear Mr. Stewart:

Re: Report on the Impacts of Mineral Development on [illegible] North of 50 Chapter [illegible]

Thank you for sending me a copy of the [illegible] summary report by the Lakehead University Study Group [illegible]

The scope of the report is very ambitious. For example, it attempts to [illegible] a number of [illegible] impacts [illegible] 220,000 square miles. This is an area the size of France. I commend the Commission for undertaking an analysis of such a land mass.

Given the large scope of this study, I believe it [illegible] that some [illegible]. Overall, however, the Commission and authors were correct in taking a broad approach. [illegible] a foundation for future work and a report that will have beneficial impact [illegible].

Yours truly,

R. W. Scott, P. Eng.

RWS/[illegible]